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THE CHINCH-BUG OUTBREAK OF 1910 TO 1915

By STEPHEN A. FORBES, State Entomologist

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CONTENTS

THE CHINCH-BUG OUTBREAK OF 1910 TO 1915

By STEPHEN A. FORBES, State Entomologist

The chinch-bug uprising of 1910–15 in Illinois was a striking example of the power of an injurious insect to avail itself of temporarily favorable conditions, and, breaking thru the ordinary checks upon its increase, to make profitable agriculture impossible for a term of years, and even to bring financial distress and ruin upon large numbers of those least able to bear unusual burdens. Making its first appearance in the fall of 1909 in a few fields of Washington county, in the southwestern part of the state, this outbreak increased rapidly year by year, spread steadily from that center with no apparent reinforcement from any outside territory, rose in 1914 to a climax of destructiveness in the central part of the then infested area, and virtually disappeared, with a rapidity amounting to collapse, in the summer of 1915. During its widest development in the fall of 1914 it occupied in destructive or dangerous numbers the whole of twenty-five counties, and a part of thirteen others. Its injuries to corn alone that year, as shown by statistics of crop production and price to be given in detail on another page, amounted to $5,045,000 at the market price of that fall; and those to wheat and oats to $1,400,000 more. This brings the total estimated crop injury for that year to $6,400,000. 1914 was, however, but one of five years of heavy loss in that part of Illinois, and it is certain that the total for the other four years was at least equal to that for this year alone. We may consequently fix upon a loss of $13,000,000 as the lowest reasonable estimate for the whole period.

Divided equally among the twenty-six counties injuriously infested at some time during the outbreak, this average of $500,000 per county might not have been felt as very oppressive; and if it had been equally distributed, like a well-levied tax, over the farms of each county according to their values, it might have been borne without serious distress. It was, however, so unequally divided, both locally and personally, that it brought financial ruin to many tenant farmers, seriously embarrassed many owners of farms, led to a heavy sacrifice of stock and other readily salable property, and compelled the purchase by farmers of hundreds of thousands of dollars' worth of grain and hay, necessary to maintain their working animals in the presence of the crop failure. The further economic consequences of this disaster are being investigated in detail by a member of the department of economics in the University of Illinois.

For the first time in the history of agriculture in this state a persistent fight against the chinch-bug was made in several parts of the area of infestation, largely by the use of organized measures for the destruction of the spring generation of the bugs at harvest-time. It

will later be shown that corn was thus saved in twenty counties in 1914 to a value of more than $700,000, by measures costing the farmers about $40,000, including under this head both materials purchased and the value of the labor of the farmer and his hired man. It is certainly safe to say that other defensive operations of this and other years added at least $300,000 to these savings, or that, in other words, at least another million dollars' worth of crops would have been destroyed if the farmers had left them wholly without defense.

It is the object of this paper to present a sufficiently detailed account of our recent chinch-bug outbreak to show its causes and those of its disappearance, to compare the cost and outcome of the various defensive measures brought into use, and especially to show the probable result if all concerned had made a general and energetic use of the best of these measures from the very beginning of the trouble. It will appear from this discussion that it is not only perfectly feasible to protect the corn crop completely in the beginning and early stages of a chinch-bug uprising, but that this is an immensely profitable undertaking; that by a thoro application of measures now well known, so large a proportion of the chinch-bugs in any badly infested area might be destroyed at this time that a developing outbreak would be practically suppressed, to the great advantage of the local community and the substantial protection of a much larger territory adjacent. This would require, however, general cooperative action, taken in the community interest as well as in that of each person whose crops are threatened at the time. Unfortunately, however, the individual farmer will commonly stop short with the best protection which he can afford his own crops, to the neglect of the further measures necessary to the protection of those of his neighbors and to the protection later, perhaps, of those of a great area exposed to destruction if an outbreak is allowed full swing. Such an outbreak is like a contagious disease or a conflagration; if wholly left to individual control, it will run its course, with only a little saved from destruction here and there, by special personal effort. If the community is to be protected it must be enabled to act in its own behalf through its official representatives, equipped and empowered to encourage, assist, and, where necessary, to require and even compel individual action which will make the community interest safe.

DETAILED COMPUTATION OF LOSSES

For a critical judgment of the amounts and values of the loss of farm crops caused by the late chinch-bug outbreak, I have first taken the statistics of production for 1914, the year in which chinch-bug injury was the most extensive and most severe, and have chosen for comparison the seventeen counties worst infested and seventeen other counties adjacent to them which were so little infested, if at all, that no appreciable injury was done to crops. The seventeen infested

counties (see Map 6) lie in a compact, roughly triangular body, with the Mississippi River from Randolph to Pike counties as the base of the triangle and Shelby county at its apex. The uninfested counties lie in an irregular zone around the margins of the infested area excepting, of course, on the western side. A comparison of the total yield and value of all crops subject to chinch-bug attack in these two areas in 1914 ought to show how large a deficiency should be charged to the chinch-bug in that year.

It was first necessary, however, to see whether the two sets of counties were sufficiently alike in average productivity to make the comparison a fair one. It seemed quite possible that, altho taken at random, they might be enough unlike in their agricultural qualities and hence in their average crop yields to make it difficult to say whether any difference manifest in 1914 was all or mainly due to insect injury. To settle this point, I have taken the statistics of corn production for these two sets of counties for the eight years from 1902 to 1909 inclusive—a period during which there was no chinch-bug injury in any part of either area; and I find that corn averaged 35 bushels per acre, during these years, in the counties which became infested by chinch-bugs in 1914, and 32 bushels per acre in those which were uninfested in that year. This difference of three bushels per acre being in favor of the infested area, it is evident that this area is at least as productive, under ordinary conditions, as the other.

The year 1914 was one of severe and destructive drouth in central and southern Illinois; and it seemed possible that the two sets of counties selected might have differed with respect to the degree of drouth in a way to add a greater weather injury to that done by chinch-bugs, and thus to make it impossible to tell just how much was due to the latter alone. Reference to the published reports of the U. S. Weather Service, gave me nineteen points in the infested area at which the weather of the season was recorded, and seventeen such points in the uninfested area. It is generally agreed that the weather of June, July, and August makes the corn crop, that of August being the most important; and I consequently brought into comparison the rainfall and temperature of the two areas for these months, with the result that the total rainfall during these months for the infested counties was found to be 8.07 inches, and that for the uninfested counties 7.85 inches—a difference of only .22 of an inch in the three months, which is too small a deficiency to have any significance in this comparison. Moreover, an examination of the monthly means of rainfall for the separate months shows that the deficiency in the infested counties was most marked in June, when it would have had the least effect upon the corn crop, and least so in July, and that in August, the most important month for the growth of corn, the rainfall was *larger* by nearly two thirds of an inch in the infested area than in the uninfested.

A similar study of the temperature records of these two sets of counties shows that the mean temperature of the uninfested area for June, July, and August, 1914, was 78.9 degrees F., and that of the infested area was 79.5 degrees, the latter counties averaging only .6 of a degree warmer than the former—a difference much too small to have any noticeable effect on the yield of crops. Evidently the weather of the season could have given no advantage to the corn crop of the uninfested counties.

Thus satisfied that these two areas might be fairly compared and that any marked difference shown by them in the yield of crops subject to chinch-bug injury must be due to the insects themselves, I have compiled the reports of the 1914 corn crop, published by the State Department of Agriculture in its crop report for December of that year. From these I find that the average yield per acre in the infested counties was 18.1 bushels and that in the uninfested counties it was 25.2 bushels, a difference of 7.1 bushels per acre which I could attribute only to chinch-bug injury. The total area of corn in the seventeen counties thus injuriously infested was, by the same crop report, 947,582 acres, and the total loss of corn at the above rate per acre was 6,727,432 bushels, which, at sixty cents a bushel, the minimum current price of corn that fall, amounted to $4,036,699.

This, however, is not all. The December report of the State Department of Agriculture shows not only the quantity of the crop but its quality as well, on a scale of ratios in which a fair average quality is rated at 100 percent. Comparing the quality ratios of the corn crop in our two sets of counties separately, I find that the corn of the infested counties was graded at 60.8 percent of an average, while that of the uninfested counties was 85.9 percent, a difference of virtually a fourth in favor of the corn of the uninfested counties. We shall have, therefore, to make a further reduction of fifteen cents a bushel in the market value of the product of the infested counties, thus increasing our loss of corn by a fourth, and bringing the total loss in 1914 for these seventeen counties up to $5,045,874.

Corn is but one of three important crops subject to destruction by chinch-bugs, the others being wheat and oats. A similar use of the crop reports to that above described gives a yield of wheat per acre in 1914 of 19½ bushels in the uninfested counties and 16 bushels in the infested counties, a difference of 3½ bushels per acre attributable to chinch-bug injury. The total acreage of wheat in the infested counties was 516,589 acres, and the average price per bushel August 1 was seventy-five cents. From these data we obtain a loss of $1,356,039 in wheat due to chinch-bug injury. The loss in oats is much less important. This crop in the infested counties occupied only 16,422 acres, with an average yield per acre of 6.1 bushels less than that in the counties uninfested. An average price of forty-one cents per bushel August 1 gives us a total loss of $41,071 for 1914.

The loss in this year on all three crops thus amounts to $6,442,984 by this computation for seventeen counties only. Twenty-two counties were, however, injuriously infested this year, fifteen of them over practically their whole area and the other seven over a part of it only. Furthermore, 1914 was but one of six years during which the chinch-bug was destructively abundant in this part of Illinois, and we shall certainly be far within the truth if we double the figures for this limited area infested in one year as our estimate for the entire damage wrought in Illinois from the beginning of the outbreak. This gives us practically $13,000,000 as the immediate sacrifice of staple crops to the chinch-bug during this period in Illinois.

SECONDARY ECONOMIC CONSEQUENCES

Secondary losses of all kinds consequent upon this primary destruction it is probably impossible to compute or to estimate with even approximate exactness; but that they were very heavy will be shown by a general study of the economic consequences, direct and indirect, immediate and remote, of this chinch-bug outbreak which is being made for me by a member of the economics department of the University of Illinois. I may here refer, however, in passing, to a single example of these secondary consequences, which I have myself drawn out of the data derived from assessors' reports on the live stock of the state, as published by the State Department of Agriculture in its statistical reports.

BEEF AND DAIRY CATTLE IN FOUR WORST INFESTED COUNTIES (2724 SQUARE MILES), AND IN FIVE UNINFESTED COUNTIES ADJACENT (2629 SQUARE MILES).

Counties	Sq. miles	Kinds of stock	Years					Percentages	
			1911	1912	1913	1914	1915	Loss	Gain
Bond	380	Beef	9,283	6,498	6,173	4,938	4,197	54.7	
		Dairy	5,632	4,506	4,731	5,204	4,788	15.	
Macoupin .	864	Beef	10,265	9,136	8,314	7,981	6,066	40.9	
		Dairy	3,304	3,205	3,237	3,399	3,501		5.9
Madison ...	740	Beef	16,680	15,005	13,503	12,154	10,574	36.6	
		Dairy	6,332	6,142	5,528	5,362	4,826	23.8	
Montgomery	740	Beef	13,834	12,451	11,206	6,724	5,715	58.7	
		Dairy	5,324	5,324	5,324	5,164	4,596	13.6	
Total	2,724		70,654	62,267	58,016	50,926	44,263	37.0	
Clark	513	Beef	6,425	4,305	3,440	2,993	2,993	51.8	
		Dairy	2,664	2,531	2,278	2,278	2,210	13.3	
Coles	520	Beef	9,837	8,066	7,421	6,679	5,544	43.6	
		Dairy	3,464	3,014	2,924	3,070	3,070	11.4	
Cumberland .	350	Beef	9,370	7,027	6,324	6,134	6,441	31.3	
		Dairy	1,993	1,594	1,674	1,758	1,899	4.7	
Effingham ..	486	Beef	11,350	10,782	10,027	8,523	8,097	28.6	
		Dairy	6,472	6,472	6,472	6,343	6,153	4.9	
Shelby	760	Beef	27,328	25,962	26,741	25,671	24,901	8.8	
		Dairy	7,378	7,378	7,378	7,378	7,230	2.	
Total	2,629		86,281	74,131	74,679	70,827	68,538	20.6	

SUMMARY OF ABOVE TABLE

Cattle	Counties	1911	1915	Decline	
				in numbers	percent
Beef	Uninfested	64,310	47,976	16,334	25.4
	Infested	50,062	26,552	23,510	46.9
Dairy	Uninfested	21,971	20,562	1,409	6.4
	Infested	20,592	17,711	2,881	13.8

Decline in four counties because of chinch-bug injury to crops: Beef cattle, 7176 (21.5%); dairy cattle, 1472, (7.4%).

Value of decline: Beef cattle, ... $358,800
Dairy cattle, ... 88,320

$447,120

To arrive at the effect of a destruction of crops by the chinch-bug upon live-stock holdings in the infested country, I have brought into comparison the number of beef and dairy cattle in infested and uninfested counties for a period of four years from 1911, when the counties chosen were generally invaded by the chinch-bug, to 1915, when the invasion came to an end. The infested counties selected were Bond, Macoupin, Madison, and Montgomery, with a total area of 2724 square miles, and the uninfested countries were Clark, Coles, Cumberland, Effingham, and Shelby, with a total area of 2629 square miles. From the foregoing table it will be seen that there was a falling off from 1911 to 1915 in the number of cattle of both classes in both groups of counties, but that this decline went much the farthest in the counties infested by the chinch-bug. While the uninfested counties lost 25.4 percent of their beef cattle and 6.4 percent of their dairy cows in these four years, the infested counties lost 46.9 percent of the former and 13.8 percent of the latter—differences of 21.5 percent of their beef and 7.4 percent of their dairy animals—all of which may be fairly attributed to the pinch of the emergency caused by the chinch-bug devastation. These ratios give us a loss on this account of 7176 beef cattle and 1472 dairy cows, which, at the average values of stock in the several counties for the year 1915 ($47 for beef and $60 for dairy animals) amounts to $447,120. It is not to be understood, of course, that this sum should be added to the losses due to the chinch-bug; it is merely a partial measure of the economic disturbance and strain which these losses produced.

THE PROGRESS AND DEVELOPMENT OF THE OUTBREAK

From its beginning in the southwestern part of Washington county in 1909, the chinch-bug outbreak expanded in 1910 to occupy an irregularly pear-shaped area lying on both sides of the Kaskaskia River and including virtually the whole of the counties of Clinton, Washington, and Perry together with a considerable part of six other coun-

ties adjacent. The northernmost locality in which an infestation was found was in the northern part of Fayette county. (Map 1.)

By the summer of 1911 the smaller, northern end of this pear-shaped area had so developed to the north and west as to make a much larger district of infestation, still pear-shaped, but with the larger end of the figure now northward. Fourteen counties were involved, seven of them lying wholly within the infested area, the northern boundary of which reached to the southern part of Christian county and the northern line of Macoupin. A tendency of the expansion to the eastward was shown by threatening numbers of chinch-bugs at single localities in Franklin and Jasper countries. (Map 2.)

During 1912 the infested district was widened and extended northward to assume a triangular form, with the Mississippi River between Jackson and Pike counties as one side of the triangle and with Cumberland county at its peak. (Map 2.) Eleven counties were now wholly included in it, and a considerable part of twelve counties additional. The northernmost point of serious infestation this season was in the southern fourth of Sangamon county. The severity of the attack was noticeably lessened in the southernmost counties infested, altho local crop injury in Hamilton and Saline counties showed that conditions to the southeast were barely below the danger line.

In 1913, (Map 3) altho there was a slight expansion of the area of injury to the northward to include the whole of Greene and Calhoun counties, the number of counties affected was reduced to eighteen, the southern and eastern angles of the area occupied in 1912 being now withdrawn or rounded off in a way to give the whole tract an irregularly hemispherical or semielliptical form with the central parts of Shelby and Marion counties at its eastern boundary and central Randolph at its southernmost extension.

There had developed by this time in parts of Madison and Macoupin counties a center of intense infestation within which nearly all crops liable to destruction were practically obliterated; and these conditions became still more serious in 1914 when the outbreak reached its climax. In this year (1914) the spring flights of chinch-bugs from their winter quarters brought them to our notice as destructively abundant either in wheat or corn over the whole of fifteen counties and in considerable parts of eleven others, the additions to the area occupied being almost wholly to the northward. (Map 4.) The northernmost line of the chinch-bug territory of this year ran a little above the southern boundaries of Adams, Brown, and Cass counties; and its farthest eastern boundary was in Effingham county. A center of virtually complete destruction lay in the counties of Jersey, Macoupin, Montgomery, Fayette, Bond, and Madison, within which it formed an oval tract about seventy-five by forty miles in greatest length and breadth. The mid-summer flight of the first generation of the bugs carried them so far outward in all directions that the fall inspection


MAP OF
ILLINOIS
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
DU PAGE
COOK
WHITESIDE
LEE
KENDALL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
GRUNDY
WILL
MERCER
PUTNAM
STARK
MARSHALL
KANKAKEE
HENDERSON
WARREN
KNOX
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
HANCOCK
McDONOUGH
FULTON
TAZEWELL
McLEAN
FORD
SCHUYLER
MASON
LOGAN
DE WITT
CHAMPAIGN
VERMILION
ADAMS
BROWN
CASS
MENARD
PIATT
MACON
DOUGLAS
EDGAR
PIKE
SCOTT
MORGAN
SANGAMON
MOULTRIE
CHRISTIAN
COLES
GREENE
SHELBY
CUMBERLAND
CLARK
CALHOUN
MACOUPIN
MONTGOMERY
JERSEY
EFFINGHAM
JASPER
CRAWFORD
FAYETTE
MADISON
BOND
CLAY
RICHLAND
LAWRENCE
CLINTON
MARION
ST. CLAIR
WAYNE
EDWARDS
WABASH
WASHINGTON
JEFFERSON
MONROE
RANDOLPH
PERRY
FRANKLIN
HAMILTON
WHITE
JACKSON
WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
PULASKI
MASSAC
Infested area 1910
Infested 1911-12
Not infested 1911-12

MAP 1.


MAP OF
ILLINOIS
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
DU PAGE
COOK
WHITESIDE
LEE
KENDALL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
GRUNDY
WILL
MERCER
PUTNAM
KANKAKEE
STARK
MARSHALL
HENDERSON
WARREN
KNOX
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
HANCOCK
McDONOUGH
FULTON
TAZEWELL
McLEAN
FORD
SCHUYLER
MASON
LOGAN
DE WITT
CHAMPAIGN
VERMILION
ADAMS
BROWN
CASS
MENARD
PIATT
MACON
MORGAN
SANGAMON
DOUGLAS
EDGAR
PIKE
SCOTT
MOULTRIE
CHRISTIAN
COLES
GREENE
SHELBY
CLARK
CALHOUN
MACOUPIN
MONTGOMERY
CUMBERLAND
JERSEY
FAYETTE
EFFINGHAM
JASPER
CRAWFORD
MADISON
BOND
CLAY
RICHLAND
LAWRENCE
CLINTON
MARION
ST. CLAIR
WAYNE
EDWARDS
WABASH
WASHINGTON
JEFFERSON
MONROE
RANDOLPH
PERRY
FRANKLIN
HAMILTON
WHITE
JACKSON
WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
PULASKI
MASSAC
Infested area 1911
Infested area 1912

MAP 2.


MAP OF
ILLINOIS
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
DU PAGE
COOK
WHITESIDE
LEE
KENDALL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
GRUNDY
WILL
MERCER
PUTNAM
STARK
MARSHALL
KANKAKEE
HENDERSON
WARREN
KNOX
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
HANCOCK
McDONOUGH
FULTON
TAZEWELL
McLEAN
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MASON
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MORGAN
SANGAMON
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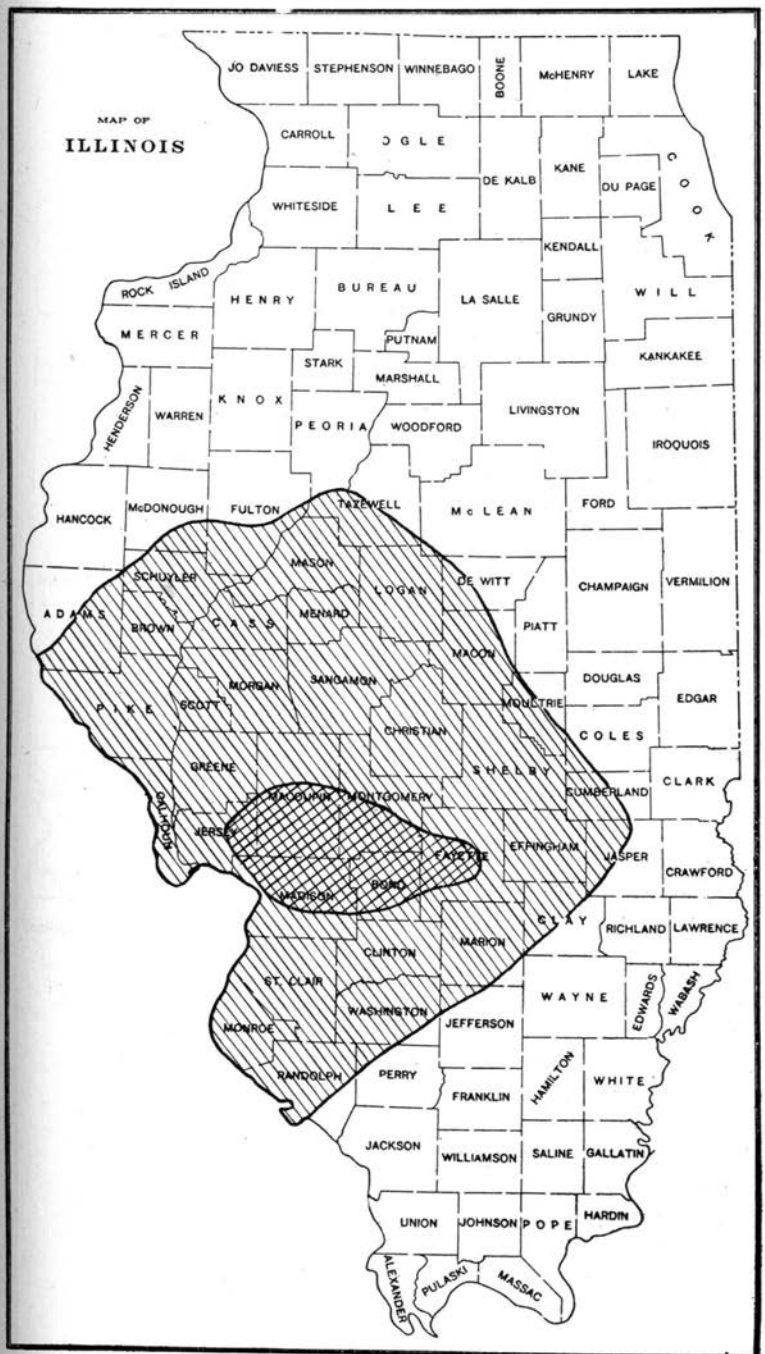
EDGAR
PIKE
SCOTT
CHRISTIAN
COLES
GREENE
SHELBY
CLARK
JERSEY
MACOUPIN
MONTGOMERY
CUMBERLAND
CALHOUN
EFFINGHAM
JASPER
CRAWFORD
FAYETTE
MADISON
BOND
CLAY
RICHLAND
LAWRENCE
CLINTON
MARION
ST. CLAIR
WAYNE
EDWARDS
WABASH
WASHINGTON
JEFFERSON
MONROE
RANDOLPH
PERRY
FRANKLIN
HAMILTON
WHITE
JACKSON
WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
PULASKI
MASSAC
Infested area 1913
Infested area 1914

MAP 3.



MAP 4. Area dangerously infested in fall of 1914, with central area of virtually complete destruction that season.

MAP 5. Area found dangerously infested in May, 1915.


MAP OF
ILLINOIS
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
DU PAGE
COOK
WHITESIDE
LEE
KENDALL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
GRUNDY
WILL
MERCER
PUTNAM
STARK
MARSHALL
KANKAKEE
HENDERSON
WARREN
KNOX
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
HANCOCK
McDONOUGH
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PIKE
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SANGAMON
SCOTT
MOULTRIE
CHRISTIAN
COLES
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SHELBY
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MONTGOMERY
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WABASH
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JEFFERSON
MONROE
RANDOLPH
PERRY
HAMILTON
WHITE
FRANKLIN
JACKSON
WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
PULASKI
MASSAC
Weather Bureau Stations
Infested counties 1914
Uninfested counties 1914

MAP 6.

of my field assistants gave us a list of forty counties dangerously infested, twenty-five of them over virtually their whole area. (Map 5.)

As a matter of fact, by the first week in May of 1915 chinch-bugs were reported dangerously abundant in wheat over the whole or nearly the whole of the following twenty-nine counties,— Adams, Brown, Cass, Menard, Pike, Scott, Morgan, Sangamon, Macon, Calhoun, Greene, Jersey, Macoupin, Montgomery, Christian, Moultrie, Shelby, Madison, Bond, Fayette, Effingham, St. Clair, Clinton, Marion, Monroe, Washington, Jefferson, Randolph, and Perry, and in parts of the following eleven others,— Mason, Schuyler, Fulton, Logan, Piatt, Douglas, Coles, Cumberland, Jasper, Clay, and Wayne (Map 6). Extraordinarily heavy beating rains in May and June so far reduced the numbers of the insects that by the 20th of June, 1915, all danger of an outbreak was over for the year and the office force organized for a field campaign was called in and broken up.

Local and General Causes of the Outbreak

The original causes of the outbreak we are studying, of its continued increase for six successive years, of its extension northward and its restriction and even retreat in the south and east, and those of its final disappearance, are to be ascertained only by careful inquiry into the conditions by which it was preceded, in the midst of which it arose, under which it was maintained, and by which it was surrounded. Such an inquiry must of course take into account all that we definitely know or may intelligently surmise concerning the effects of weather, soil, crops, parasites, predaceous enemies, and contagious diseases upon the rate of insect multiplication.

The weather relation may be very briefly described. Unusually warm weather, continued thru each year's breeding season of the bugs—that is, from May to August inclusive—and the absence of heavy beating rains during this period of the hatching and growth of the young, especially during June and August, are conditions generally regarded as favorable to a high rate of increase; while weather cooler than normal during the late spring and summer, accompanied by an abundance of rain falling in beating storms in late May, June, and August, but especially in June, may put an end to a destructive outbreak in a single year. The crop relation may be described with equal brevity. Favorable weather conditions will take first effect, other things being approximately equal, in an area where the crops are most largely those upon which the chinch-bug can maintain itself—that is, the cereal crops and the forage grasses—and where those crops are so massed and so distributed that the bugs can easily find their way to wheat in spring and to oats and corn at and soon after the time of the wheat harvest. It is also commonly believed that an outbreak is most likely to appear in Illinois where a sufficient acreage of winter wheat is so

well distributed as to furnish abundant pasturage to the adult bugs when they scatter abroad from their winter quarters, and to the young of the first generation hatching in the field to which their parents have been drawn for food.

By an examination of the records of the U. S. Weather Bureau and the data of crop production in southern Illinois for 1907, 1908, and 1909, as published by the State Department of Agriculture, I am led to the conclusion that an immediate cause of the beginning of the Washington county outbreak was the warm weather of the spring and summer of 1908 and 1909 and the character of the farm crops predominating in the country where the trouble began.

The U. S. Weather Bureau stations nearest the fields in which the chinch-bug was first noticed in 1909 were those at Tilden and Sparta, in the northeastern part of Randolph county, the first close to the southwest corner of Washington county and the second about six miles farther south. The weather records were taken at Tilden up to 1909 and at Sparta thereafter. The average temperature and rainfall data here for the four months from May to August inclusive are given in the following table. The minus sign before a number indicates degrees of temperature or inches of rainfall *below* the normal for the station, and a plus sign indicates degrees or inches *above* the normal.

TOTAL DEPARTURES FROM NORMAL TEMPERATURE AND RAINFALL, MAY TO AUGUST, 1907–1911, RANDOLPH CO., ILL.

Year	Temperature	Rain	Remarks
1907	— 5.4	+3.47	Cool and wet
1908	+ 5.1	+3.17	Warm and wet
1909	+ 4.2	—0.26	Warm and normal
1910	—10.1	+3.24	Very cool and wet
1911	+10.4	—6.13	Very warm and very dry

It will be seen that 1907 was a year unfavorable to chinch-bug increase, being both cool and wet, altho the change to warmer weather began in midsummer of that year, July and August averaging 1.5 degrees above the normal. 1908 opened with an early spring, the mean temperature of March being 6.8 degrees above the normal, and it continued warm until October, except for a drop to normal temperature in June and July. In 1909, June and August were warm in Randolph county, the excess temperature of August especially rising to a mean of 4.2 degrees. This, with a shortage of 3.12 inches in the rainfall of that month, when young chinch-bugs of the second generation were hatching in the corn, seems to have been the match which set off the explosion, for it was in the corn fields of that fall that the chinch-bug was first noticed in extraordinary abundance. The following spring it reached numbers to do considerable injury to wheat, and later in the season to corn also, in at least nine counties, as already reported. The extent and amount of injury by chinch-bugs

in 1910 makes it very likely that infestation actually began over much of this area of injury in 1909, and farther on in tracing the relations of the outbreak to prevailing crops I have assumed that this was the fact.

How little a deficient rainfall can have had to do with the commencement of this outbreak is shown by the fact that there was no dry summer in this district during these years until 1911, that of 1909 being virtually normal as to rainfall, and May to August in 1907, 1908, and 1910 being decidedly wet in Randolph county, with an excess of rainfall varying from 3⅕ to 3½ inches for each of these three years.

At this point the inquiry will naturally arise whether there were not other places in southern Illinois where the spring and summer weather of these years was equally favorable to a rapid multiplication of the chinch-bug, but where nothing of the sort actually occurred. As an answer to this question I have prepared the following table comparing temperatures and rainfall at the southern Illinois stations in 1908 and 1909. From this it will be seen that both Flora and Cobden, in Clay and Union counties, show conditions quite as favorable to the chinch-bug as those at Tilden, in that the breeding months were warm and dry at both the former in 1908, and warm at both in 1909 with a rainfall a little below the normal at Flora and less than an inch above the normal at Cobden.

DEPARTURE FROM NORMAL TEMPERATURE AND RAINFALL, SOUTHERN ILLINOIS STATIONS, MAY TO AUGUST, 1908–09

Weather stations	1908		1909	
	Temperature, degrees	Rain, inches	Temperature, degrees	Rain, inches
Albion	+2.6	—2.96	—0.6	+0.57
Cobden	+1.4	—3.50	+4.5	+0.86
Flora	+5.5	—3.50	+3.8	—0.18
Greenville	—3.4	+4.91	+0.5	—0.64
McLeansboro	0.0	—2.45	+1.5	—1.21
Mt. Vernon	+4.0	—1.88	+1.8	+0.65
Olney	+1.9	—1.37	—1.3	+1.31
St. John	—2.9	—0.04	+2.7	—0.35
Tilden	+5.1	+3.17	+4.2	—0.26

Evidently there must have been something other than the weather of these two years to prevent the appearance of destructive numbers of the chinch-bug in the districts around these two stations. It is when we compare the three counties with regard to their agricultural conditions, that we find differences having an important bearing on our inquiry.

Clay county differed from Washington county in 1909 especially in the smaller percentage of its area in wheat (1 percent in Clay county and 12.6 percent in Washington), and in the smaller area in

RATIO OF THE AREA IN EACH CROP TO THE AREA IN ALL THE CEREAL AND FORAGE CROPS TAKEN TOGETHER

Counties	Wheat percent	Oats percent	Corn percent	Forage percent
Washington	35.3	16.7	26.1	21.5
Clay	3.9	10.2	43.2	42.7
Union	32.2	5.3	25.3	37.3

PERCENTAGES OF TOTAL AREA OF EACH COUNTY IN EACH CROP

Counties	Wheat percent	Oats percent	Corn percent	Forage percent	Totals
Washington	12.6	6.1	9.1	7.7	35.5
Clay	1.0	2.8	11.7	11.3	26.8
Union	8.6	1.4	6.8	10.0	26.8

ACRES IN CEREAL AND FORAGE CROPS IN WASHINGTON, CLAY, AND UNION COUNTIES IN 1909

	Washington	Clay	Union
Wheat	45,041	3,106	22,116
Oats	21,793	8,233	3,563
Corn	33,289	35,011	17,450
Pasture	19,915	17,945	19,385
Hay	7,609	16,675	6,251
	127,647	80,970	68,765

TOTAL AREAS IN ACRES

	Washington	Clay	Union
Total areas	356,480	298,240	256,000
Areas under cultivation	264,837	228,469	132,084
Percentage cultivated	74.3	76.6	51.6

crops on which the chinch-bug can live and breed (26.8 percent in Clay and 35.5 percent in Washington). Union county, on the other hand, differed from Washington in the fact that it had only about two thirds as large a ratio of its area under cultivation (51.6 percent to 74.3 percent), two thirds as much of its area in wheat (8.6 percent to 12.6 percent), and a little more than one fifth as much in oats (1.4 percent to 6.1). Otherwise stated, Washington county had nearly 19 percent, and Union county only 10 percent, of their total areas in those crops on which the chinch-bug depends mainly for food in spring. Union county also differs from Washington in its hilly and broken character, the cultivated fields being much more scattered and isolated.

This brings us to a general consideration of the effects of the kinds and distribution of crops on a chinch-bug infestation as shown in the location and progress of this outbreak. For an investigation of this subject I have brought together the crop data for 1909 and 1910 of

nine counties within the area seriously infested in those years, and of nine other counties adjacent, but not infested at that time, as shown in the tables following.

CROP AREAS, 1909, INFESTED COUNTIES

Counties	Wheat	Oats	Corn	Forage
Madison	63,820	5,881	67,767	73,228
Bond	14,406	9,025	27,798	48,742
Fayette	16,457	7,948	31,682	77,567
Marion	819	4,306	26,298	56,376
Clinton	37,530	24,059	46,156	47,297
St. Clair	59,789	2,922	39,667	47,898
Randolph	54,384	1,547	24,530	31,248
Washington	44,777	21,793	35,619	27,524
Perry	28,288	10,434	16,784	15,726
Totals	320,270	87,915	316,301	425,666

Total of above crops ..... 1,150,152 acres
Total of cultivated land ..... 2,296,263 acres
Total area ..... 3,284,480 acres
Ratio of acreage of each crop to total acreage of all above crops:—wheat, 27.8 percent; oats, 7.6 percent; corn, 27.5 percent; forage, 37 percent.
Ratio of area in above crops to total area of cultivated land, 50 percent.
Ratio of cultivated land to total area, 70 percent.
Percentage of total area in each crop:—wheat, 9.7; oats, 20; corn, 9.6; forage, 13; total, 34.3.

CROP AREAS, 1909, UNINFESTED COUNTIES

Counties	Wheat	Oats	Corn	Forage
Effingham	4,422	9,935	48,732	56,394
Jasper	286	982	19,582	14,065
Richland	993	7,694	19,755	48,490
Clay	3,089	8,233	35,011	34,620
Wayne	684	1,031	39,709	62,549
Jefferson	2,983	8,379	24,983	51,231
Hamilton	360	9,247	47,342	33,299
Franklin	1,148	12,687	30,615	32,376
Williamson	2,660	6,986	35,560	20,307
Totals	16,625	65,174	301,289	353,331

Total of above crops ..... 736,419 acres
Total of cultivated land ..... 2,033,114 acres
Total area ..... 2,759,680 acres
Ratio of acreage of each crop to total acreage of all above crops:—wheat, 2.3 percent; oats, 8.9 percent; corn, 40.9 percent; forage, 47.9 percent.
Ratio of area in above crops to total area of cultivated land, 36.2 percent.
Ratio of cultivated land to total area, 73.7 percent.
Percentage of total area in each crop: wheat, 0.6 percent; oats, 2.3 percent; corn, 11.0 percent; forage, 12.8 percent; total, 26.7 percent.

From these tables it will be seen that the nine infested counties have an area of about three and a quarter millions of acres, of which 50 percent was in the cereal crops and the forage grasses (the chinch-bug crops, in other words), and that nearly 28 percent of the area of these crops was in wheat, about the same in corn, 7.6 percent in oats, and 37

percent in hay and pasture land. It would have been difficult indeed to plan a cropping of these counties better calculated to breed and nourish the chinch-bug during a time favorable to its rapid increase. With an abundance of wheat for the first generation and of corn for the second, with oats enough to ease the way from the one crop to the other after the wheat harvest, with a large area in the permanent grasses available at all times as an emergency food when the more succulent cereals were wanting, and with weather favorable to a large production of eggs and a successful hatching and rapid growth of the young; it was no miracle that brought the chinch-bugs out in unmanageable numbers.

In the nine uninfested counties, on the other hand, with an area of two and three quarters millions of acres, we see in the smaller percentage of the chinch-bug crops (36.2 percent here as against 50 percent in the other counties) and especially in a ratio of winter wheat only about one twelfth that of the infested counties (2.3 percent as against 27.8 percent), at least a partial explanation of the freedom of these counties from chinch-bug attack.

It was rather unfortunate for southern Illinois that wheat was a peculiarly tempting crop at the time when the agriculture of the region was threatened with ruin by an insect which finds in an abundance of wheat its most favorable food. The price of wheat in 1909 led to an increased acreage in that crop in 1910, even in the infested and endangered counties. In our nine infested counties the area in wheat rose from 27.8 percent in 1909 to 31 percent in 1910, the other crop areas being diminished a little or remaining virtually unchanged. In the nine uninfested counties the change was still greater, from 2.3 percent in wheat in 1909 to 7.3 percent in 1910, oats also coming up here from 8.9 percent to 12.4 percent, the corn and forage grasses falling off proportionally. The total acreage of the chinch-bug crops increased in these uninfested counties from 36.2 percent (1909) to 42 percent (1910). The contrast in crops between these groups of counties continued marked in 1910, however, in respect to the area in wheat, which was more than four times as large in the infested counties as it was in the uninfested.

CROP AREAS, 1910, INFESTED COUNTIES

Counties	Wheat	Oats	Corn	Forage
Bond	19,016	10,379	24,462	46,716
Clinton	20,165	10,290	14,876	15,583
Fayette	32,914	8,504	33,900	76,858
Madison	65,100	6,234	67,767	70,228
Marion	901	4,737	28,928	49,968
Perry	31,117	11,686	17,959	14,485
Randolph	54,384	1,624	24,530	30,516
St. Clair	60,985	2,805	38,477	40,047
Washington	45,673	21,793	32,769	26,148
Totals	330,255	78,052	283,662	370,549

Totals of above crops .....1,062,518 acres
Total of cultivated land.....2,296,263 acres
Total area .....3,284,480 acres
Ratio of acreage of each crop to total acreages of all above crops: wheat, 31 percent; oats, 7.3 percent; corn, 26.7 percent; forage, 34.9 percent.
Ratio of area in above crops to total area of cultivated land, 52 percent.
Ratio of cultivated land to total area, 70 percent.
Ratio of area of each crop to total area: wheat, 10 percent; oats, 2.4 percent; corn, 8.6 percent; forage, 11.3 percent; total, 32.3 percent.

CROP AREAS, 1910, UNINFESTED COUNTIES

Counties	Wheat	Oats	Corn	Forage
Clay	4,170	9,056	33,260	32,952
Effingham	35,964	45,417	44,888	82,915
Franklin	1,297	13,829	31,840	31,973
Hamilton	400	10,911	44,975	32,482
Jasper	243	1,129	18,995	11,293
Jefferson	4,624	9,887	24,483	51,777
Richland	1,092	8,771	20,743	49,251
Wayne	752	1,217	42,489	61,857
Williamson	13,586	5,705	36,649	33,178
Totals	62,128	105,922	298,322	387,678

Total of above crops ..... 854,050 acres
Total of cultivated land.....2,033,114 acres
Total area .....2,759,680 acres
Ratio of acreage of each crop to total acreage of all above crops:—wheat, 7.3 percent; oats, 12.4 percent; corn, 35 percent; forage, 45.3 percent.
Ratio of area in above crops to total area of cultivated land, 42 percent.
Ratio of cultivated land to total area, 73.7 percent.
Ratio of area of each crop to total area: wheat, 2.2 percent; oats, 3.8 percent; corn, 10.8 percent; forage, 14 percent; total, 30.8 percent.

As another method of ascertaining the effect of the kind of cropping upon the extension of chinch-bug injury, I have brought into comparison the crop areas in 1911 of four counties adjacent to the infested area which were not themselves infested in this year but were invaded by the chinch-bug in the year following, and those of four other counties adjacent which were not infested in either year. (Map 2.) For convenience of discussion, I will call the four counties not subsequently infested (Clay, Franklin, Jackson, and Jefferson) Group A, and the four subsequently infested counties (Jersey, Macoupin, Madison, and Montgomery) Group B. The following table is the basis of my comparison.

CROP AREAS, 1911

Counties, Group A (not infested)				
	Wheat	Oats	Corn	Forage
Clay	4,587	7,879	29,934	31,810
Franklin	1,128	13,414	30,248	31,565
Jackson	20,794	750	13,321	15,722
Jefferson	5,872	9,096	21,300	50,346
Totals	32,381	31,139	94,803	129,443

Counties, Group B (subsequently infested)

	Wheat	Oats	Corn	Forage
Jersey	17,827	860	34,286	19,968
Macoupin	23,844	10,427	41,280	51,173
Madison	65,100	6,047	69,122	70,029
Montgomery	37,275	22,712	70,383	80,707
Totals	144,046	40,046	215,071	221,877

Acreage in above crops:
Group A, 287,766 acres
Group B, 621,040 ''
Cultivated area, 1911:
Group A, 837,749 acres
Group B, 1,036,956 ''
A=counties north of infested area of 1911; infested in 1912.
B=counties southeast of infested area of 1911; not infested in 1912.

CROP RATIOS, 1911 (RATIO OF AREA IN EACH CROP TO TOTAL AREA UNDER CULTIVATION)

Group	Wheat	Oats	Corn	Forage
A	3.86%	3.71%	11.3%	15.4%
B	13.9 %	3.8 %	20.8%	21.4%

From this table we see that the area in chinch-bug crops was much smaller in Group A (34.3 percent) than in Group B (59.9 percent), and that the ratio of wheat in Group B was three and a half times as great as in Group A. In other words, the outbreak extended from the area infested in 1911 northward over country planted largely to cereals and grasses, and with a high ratio of wheat, but did not spread over counties to the east and southeast with a smaller area in these chinch-bug crops and a materially smaller one in wheat.

Another reason appears, however, for this rapid northward spread of the chinch-bug outbreak, in a fact brought especially to my attention by one of my field assistants, Mr. W. P. Flint. The principal chinch-bug flights—the dispersal flights—are those which carry the insect over new territory in spring when it emerges from its winter quarters, in midsummer when the first generation reaches maturity, and in fall when the insect leaves the fields in search of winter quarters. The principal spring and fall flights are especially likely to occur upon warm days following upon raw and chilly ones, conditions under which the prevailing winds are from the south.

This fact is illustrated by the following data of the direction and velocity of the wind at Springfield at times when our field notes show the occurrences of considerable flights of chinch-bugs in the infested area.

Date	Direction of wind	Velocity
May 4, 1911	West	13 miles, maximum
" 5, "	East and southeast	12 miles, "
" 6, "	South	12 miles, "
" 7, "	South	15 miles, "
Sept. 25, "	Variable	
" 26, "	Northeast around to south	
" 27, "	South and southwest	
April 24, 1912	Southwest and west	18 miles,
May 1, "	South and southwest	22 "
" 2, "	Southeast and east	21 "
" 3, "	Southeast and south	14 "
" 4, "	South and southeast	18 "
April 18, 1913	West and northwest	18 "
" 21, "	South	19 "
" 22, "	South and southwest	25 "
" 23, "	South	31 "
" 16, 1914	West and southwest	8 "
" 16, "	South and southwest	11 "
" 18, "	South	36 "
Sept. 20, "	Southeast and south	16 "
" 21, "	South	21 "

It is a matter of common observation that the chinch-bug tends to move with the wind, even when on the ground, and much more so, of course, when on the wing. The wider and more rapid extension of an outbreak to the north than in any other direction is a necessary consequence; and the later stages of the spread of the present one into the northernmost counties of its area seems, indeed, to have been due mainly to this cause. Altho continuing much the most destructive in the distinctively wheat-growing counties, it invaded counties to the northward in which wheat was a relatively unimportant crop. In 1913, for example, it spread to the north over the greater part of the counties of Christian and Sangamon, the cropping of which, as shown below, gives us but 9.8 percent of their area in wheat in 1912 and 7.6 percent in 1913. Corn was, in fact, the predominating crop in these counties, with the forage plants next in area and oats averaging only about as much as wheat.

CROP AREAS, 1912

Counties	Wheat	Oats	Corn	Forage
Christian	18,059	5,846	109,303	74,915
Sangamon	21,136	29,196	99,596	41,581
Totals	39,195	35,042	208,899	116,496

Total of above crops ..... 399,632 acres
Total area ..... 1,009,280 acres
Total in cereal and forage crops 39.6 percent of area.
Ratio of each crop to total of above crops: wheat, 9.8 percent; oats, 8.8 percent; corn, 52.3 percent; forage, 29.1 percent.

As a general conclusion from the foregoing discussion we may say that our outbreak made its start in the wheat-growing counties under conditions of high spring and summer temperatures for two successive seasons, but with no marked deficiency of rainfall; that it spread thence by a process of overflow in the direction of the prevailing winds at the times of the dispersal flights of the bugs, and into wheat-growing counties to the virtual exclusion of those in which wheat was not an important crop; that it reached its most destructive abundance in wheat country to the northward of its place of origin; and that it was finally swept in this direction into areas where wheat is decidedly secondary to corn, hay, and pasture grasses, doing there a diminished damage, however, except to corn which grew beside infested fields of wheat.

It must be admitted, however, that proof of the immediate dependence of chinch-bug increase on high summer temperatures and moderate rainfall and upon the character of the agricultural crops, is not here so clean-cut and positive as to put these conclusions altogether beyond question. A great chinch-bug outbreak is, as a rule, general over a wide territory—the present one, for example, covering the greater part of Oklahoma, Kansas, and Missouri, besides some forty counties in Illinois. It began, indeed, earlier in the West than in Illinois itself, chinch-bugs being destructive there in the spring of 1907, more than two years before our first observation of its prevalence in this state. The occurrence and maintenance, for a term of years, of any uniform weather conditions over so great an area seems quite improbable; and the problem is one which should at any rate be studied over the entire territory of an outbreak as a unit rather than in a fragment of it on its margin. Furthermore, all our conclusions are based on field observations only, and are wanting in the precision and conclusive character of experimental investigation. Just how varying temperatures affect the chinch-bug; at which degree of heat it becomes active; how high a temperature is most advantageous to it, and at what degree is begins to suffer; how long a season is most conducive to its rapid multiplication; and what are the effects upon it of different degrees of humidity at varying temperatures,—these are all questions which must be answered before a complete solution of the problem of meteorological relations can be reached.

The sensitiveness of the chinch-bug to differences of temperature is well shown by its habits in the field when it is attempting to escape from the dried-up stubble after harvest. It does not ordinarily begin its movements in the forenoon until the weather of the day warms up to about 74 degrees F.,* and on hot bright days its activities cease in

*Upon this point the following field-notes by Mr. Flint for the summer of 1912 have an interesting bearing:

"The temperature at which chinch-bugs, assembled just within the road-oil line, begin to move in the forenoon was noticed on several days. They were never seen in motion when the thermometer was below 74 degrees F., and no effort to es-

the middle of the day from 10 or 11 o'clock until 3 or 4 in the afternoon, the bugs sheltering themselves meantime against the heat as best they can. As night approaches they become quiet again, and they make no migration movements after twilight falls.

THE ARREST OF THE OUTBREAK IN 1915

Effect of the Weather.—Whatever uncertainty may attach to our judgments of the principal causes of the origin and continuance of our chinch-bug uprising, there can be none as to those of its suppression in 1915, as will be seen from the following narrative abstracted from the notes of Mr. W. P. Flint, in charge of my field operations during that year.

Examinations of chinch-bugs in their winter quarters during the latter part of March, 1915, and counts of living and dead bugs, showed that only a very small percentage of them had died during the winter. Thruout the greater part of the infested area they were active in their places of hibernation during the warm days from the 5th to the 9th of April, but few or none flew into wheat fields at this time. During a second warm period, beginning April 16, a general flight into the fields began, and by the 25th of that month nearly all the bugs were in the wheat or the oats.

Eggs were very abundant in the wheat by April 28 in the central part of the infested area, and by the first week in May in the northern part also, but owing to cool and rainy weather, beginning in most sections about May 3, their hatching was much delayed. Fifteen collections of the eggs brought in from the field before May 11 hatched, on an average, twenty-eight and a half days thereafter, and some not until forty-three days after they were brought in.

Young bugs were first noticed in the fields May 17, but they were not at all abundant until the end of May. From May 20 to 30 very hard beating rains fell over the whole infested area. At Springfield the total rainfall from May 25 to 27 was 6.26 inches, and it was nearly as great at several other places. These rains caused the death of most of the adult chinch-bugs in that part of the infested area. Dead

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cape from the stubble fields surrounded by barriers was ordinarily made until about the middle of the forenoon. More detailed data are as follows:

"July 18, 1912. The morning bright and very clear; temperature at 5:30 a. m., 66 degrees, no movement of the bugs; 6 a. m., temperature 68.5 degrees, no movement; 7 a. m., temperature 74 degrees, slight movement among such of the chinch-bugs as were directly exposed to the rays of the sun; 7:30 a. m., temperature 78 degrees, slight general movement in field and in post-hole traps, but no bugs crawling to the road-oil line. July 19. Morning bright and clear; temperature, 5:30 a. m., 61 degrees F., no movement; 6 a. m., 64 degrees, no movement; 7 a. m., 70 degrees, no movement; 7:30 a. m., 76 degrees, slight movement among the bugs, altho no real effort was made to leave the field."

According to afternoon observations, recorded in Bulletin 191 of the Kansas Agricultural Experiment Station, it appears that in the dry cloudless weather of 1911 and 1912 "the bugs usually began to escape about 4 p. m., reaching the maximum from 5 to 5:30, and usually ending by 7 p. m."

bugs were numerous on the ground in all infested fields, some showing the white fungus of Sporotrichum, but many with no trace of that or any other fungous growth. At least 95 to 99 percent of the young bugs that had hatched before May 25 were killed by these beating rains. In all the more heavily infested fields the ground around the wheat plants looked as if sprinkled with red pepper because of the abundance of young bugs imbedded there in the mud; and in only one instance did these dead young give any evidence of fungous infection. Where streams rose and flooded bottomland wheat in a way to leave the tops of the plants projecting above the flood, the bugs availed themselves of this means of escape from the waters, climbing the stems and remaining until the ground was exposed again, and then returning to the bases of the wheat plants.

The period of egg-hatching extended from May 20 to June 20. It was difficult to say just when the young were most abundant in the fields, the weather for nearly all May and June being an alternation of short moderately warm periods, during which the eggs hatched in fair numbers, and heavy rains which the young were too small and weak to survive. There were thus alternating periods of a moderate abundance and unusual scarcity of the young in all the central and northern parts of the infested area; and by June 20 all danger of serious injury by chinch-bugs in 1915 had passed. Nevertheless there were young enough in a few fields to have warranted their destruction by means of the creosote line and post-hole traps, but when these fields were harvested, about July 1, they contained, owing to the wetness of the season, so heavy a growth of wild grasses available as food for the chinch-bugs that there was no movement of the insects out of the stubble.

Eggs of the second generation were fairly numerous in corn fields by the second week in August, and young were appearing in moderate numbers by the middle of that month; but many were killed by the heavy rains which fell over the whole of the infested area August 20 and 21. Over eight inches of rain fell at a number of places in the southwestern part of the state during these two days. These heaviest rains of the season had much less effect than those of May and June, since most of the bugs were at this time in the corn where they were protected from the driving force of the storms. From August 20 to about September 7 eggs and young could be found in moderate numbers in scattered fields in all the more heavily infested territory, and most of these young reached maturity and went into winter quarters. Examination of the usual hibernating places made during the winter of 1915-16 have convinced us, however, that chinch-bugs are not now present in sufficient numbers to cause any damage in 1916, unless conditions should be unusually favorable to their multiplication.

While the exceptional spring and summer rains were thus the principal causes of the arrest of this destructive insect invasion, certain

slower and less effective agencies had been for some time at work in the same direction, one of them at a rapidly increasing rate. There was no notable development of fungous disease such as has sometimes been useful in hastening the disappearance of an unusually injurious outbreak, but there was a considerable number of predaceous insects which found in the chinch-bug horde an acceptable and convenient food supply; and a minute insect parasite of the eggs of the chinch-bug had appeared in the fields and begun to multiply much more rapidly than the chinch-bugs themselves—at a rate, indeed, to check severely or perhaps to suppress entirely the uprising within a year or two longer.

Effect of Predaceous Insects.—My field assistant, Mr. W. P. Flint, reports a list of some twenty species of predaceous insects—mostly lady-beetles, ground beetles, bugs (Hemiptera), and larvae of lacewing flies—which were eating chinch-bugs in the fields searched by him. By carefully collecting and counting chinch-bugs and their insect enemies in twenty-six separately measured square yards of wheat stubble in different parts of central Illinois, he found that the number of these predaceous insects to that of the chinch-bugs in these fields in July, was about as 1 to 17; and by insectary experiments in feeding the various species of these insect enemies with living chinch-bugs, he further found that the predaceous insects occurring on an average square yard of stubble would eat 11 chinch-bugs a day if confined to them for food. This is equivalent to about a million a day in a 20-acre field—a number much too small to have any marked effect upon a serious infestation.

In addition to the foregoing I have an interesting note of an observation made June 16, 1914, by Mr. P. A. Glenn, of my office staff. While observing chinch-bugs in a Sangamon county corn-field he noticed that ants (*Formica fusca subsericea*) which had their burrows in corn hills were attacking and killing many of the chinch-bugs that came near the corn, the ground around the hill being thickly strewn with the dead bodies of the bugs. The hill of corn which the ants were defending was in a healthy condition and comparatively free from the bugs, while the hills around it were covered with chinch-bugs, many of them killed. Numerous other hills of corn in the part of the field overrun with chinch-bugs were being similarly defended by the ants.

Mr. Flint also reports a similar habit of the common corn-field ant (*Lasius niger americanus*). When spraying corn with Black Leaf 40, he twice saw this ant capture and drag away stupefied chinch-bugs; and he found the remains of 27 adult chinch-bugs in one of its nests.

Effect of the Egg Parasite.—An egg parasite of the chinch-bug (*Eumicrosoma benefica* Gahan) discovered by McColloch in Kansas in 1913* was first found in Illinois January 14, 1914, hibernating

*Canadian Entomologist, Vol. 45, p. 342.

among corn-field grasses in Macoupin county, and again in a similar situation March 3, near Marissa, in St. Clair county. Other specimens were obtained June 24 by keeping in closed dishes chinch-bugs' eggs collected May 5 at Plainview, in Macoupin county, and again August 6 from eggs collected June 10. The extent of parasitism thus disclosed was, however, very small. From 11,521 eggs obtained between May 7 and September 9 at various points in twenty-four counties, and kept under normal conditions, parasites emerged from only 140, 9 others dying, however, in parasitized eggs without completing their transformations. In other words, only about 1.5 percent of all the eggs collected during this period were found parasitized. Nevertheless, at some of the points where the presence of the parasites was demonstrated in the fields, from a fourth to a third of the eggs were parasitized, and the general average of parasites at nine such points in six counties was 4.2 percent (149 parasites to 3524 eggs). In Kansas during this same year the percentage of egg parasites at Manhattan varied from .016 of 1 percent in May to 9 percent in August, and 25 percent in September, the last ratio being based, however, on a very small number of eggs collected. The ratio for the 11,000 eggs obtained at that place during the season was 15 percent parasitized, instead of the 1.5 percent in Illinois. In sixteen Kansas localities from which eggs were gathered in July and August, 1914, the percentage of parasitism was 14.5, while in Illinois the ratio for 1356 eggs collected in the same months in twenty-two localities was 10.6 percent.

The chinch-bug egg parasite had evidently made an excellent start in Illinois in 1914, materially helped on by our importation of parasitized eggs from Kansas, when the weather intervened to destroy in great measure both the chinch-bugs and the parasites of their eggs. The following year (1915), parasitized eggs of chinch-bugs were found in fifteen Illinois counties instead of the six of the year preceding, but only 1.3 percent of the eggs collected in April, May, and June at these places were parasitized (128 parasites to 9972 eggs). It seems probable that the minute and delicate-winged parasites were even more susceptible to injury and destruction by the stormy, drenching weather of the season than were the chinch-bugs themselves.

ARTIFICIAL MEASURES OF CONTROL

It is evident from the foregoing that the "natural enemies" of the chinch-bug did it no serious harm in Illinois during the six years of its destructive prevalence here, and it remains to see what was attempted, what was done, what might have been done, and what may be done hereafter in any similar case arising, by man, the arch-enemy of all the injurious insect species. Other so-called "enemies" of the chinch-bug are really its friends, in the sense that they find it useful to them

and avail themselves of its useful qualities. It is to their advantage, indeed, that it should increase at the highest rate and prevail in the largest numbers possible; while man alone would destroy it utterly as never useful to him and always injurious whenever it becomes abundant. To this end four things are necessary: a knowledge of the habits, haunts, and life history of the chinch-bug such as will enable us to see when, where, and how it can be attacked most effectively; a knowledge of the best methods and materials for the operation against it; prompt and determined action at the critical time by the individual farmer whose interests are threatened; and cooperative arrangements and agreements which shall bring to bear upon the undertaking the joint effort of all in the common interest.

It is well and widely known that there are two periods in the year when the chinch-bug may be successfully attacked, under favorable conditions. These are the winter season, when it is in hibernation among dead grasses and under the shelter of leaves and other rubbish on the ground; and the time of wheat harvest, when it must escape from the deadened wheat fields on foot to find fresh food in other crops.

BURNING OUT IN WINTER

In the dry climate of the "western plains" the dead bunch-grasses and other winter harborage of the chinch-bug can commonly be burned in winter close enough to the ground to destroy the greater part of the insects in their winter quarters; and marked success has been had with this method, especially in Kansas, where it has lately become a principal reliance in chinch-bug campaigns. Occasionally in Illinois the weather is dry enough to make this method feasible; and in the hope that the winter of 1911-12 might prove to be one of this character, I issued in November, 1911, a circular of information, warning, and advice with a view to a general clearing up and burning over of the winter shelters of the chinch-bug in a way and at a time to destroy the insects themselves. Considerable preparations were made to this end by farmers in several localities; but the character of the winter weather was such that very little could be done; and the same was true of the three later winters during which the chinch-bug was present in extraordinary numbers. The dead grass and the rubbish on the ground were but rarely dry enough to burn to the deeper layers where the chinch-bugs were wintering; and then only locally and for a very short time. Furthermore, in the climate of central and southern Illinois the stems of the more abundant kind of bunch-grass (*Andropogon virginicum*), the favorite wintering place of the chinch-bug, remain green at their bases for an inch or two above the ground, and hence can rarely be burned far enough down to destroy the insects nestled away among them. (Figs. 1, 2, 3.)

The burning method was however tested practically by my field

assistants, Flint and Smith, near Coulterville, in Randolph county, at several times between December 19, 1911, and March 20, 1912. By selecting the most favorable times and places more than half of the bugs were disposed of, as was ascertained by carefully collecting and counting all the chinch-bugs in several bunches of grass, or on measured surfaces of other shelter, both before and after the field was burned over. One of the most definite tests of this description was made March 19 and 20, 1912, by counting the bugs in twenty stools of bunch-grass—ten before and ten after the field was burned. In this field the ten unburned bunches contained 5198 living and 335 dead chinch-bugs, and the ten burned bunches contained 2767 living bugs and 767 dead. If we may assume that the number of living insects was practically the same in these two lots of bunches before the burning, then 47 percent of the chinch-bugs (2431) were destroyed in the lot burned over, 432 of these being merely killed and the remainder burned up. In the whole series of this year's experiments with bunch-grass, the chinch-bugs in 46 unburned and 40 burned stools of these plants were counted in all, with the result that the unburned stools averaged 554 and the burned stools 280 living chinch-bugs each. According to these data about half the bugs had been killed by burning the grass.

Furthermore,according to counts made of measured areas, each a foot in diameter, covered with leaves, weeds, and other similar rubbish, (Fig. 4) twenty-five such patches yielded, unburned, 12,456 chinch-bugs (498 to the patch), and eight others yielded 121 chinch-bugs each after they had been burned off. This would indicate the destruction of 76 percent of the bugs under such shelter by the operation. In brief, from 50 to 75 percent of the chinch-bugs contained in these winter shelters seem to have been destroyed by our experimental burnings under these peculiarly favorable conditions—sufficient evidence of the utility of this method when such conditions are general and continuous rather than local and temporary. Southern Illinois lends itself, however, rather poorly to the burning-out method, an abundance of shelter for hibernating insects being afforded in thickets, woodland borders, hedges, and other miscellaneous places of winter resort which it would be quite impossible to burn over at all generally. Nevertheless, both our own experience and the successful work of others show the very great value of this method whenever and wherever conditions favor its use. It is the least expensive of all operations against the chinch-bug, and should be undertaken whenever possible by cooperative, neighborhood measures, both in one's own interest and in that of the community at large.

DESTRUCTION OF CHINCH-BUGS AT THE WHEAT HARVEST

The best means known in 1909 for preventing the escape of chinch-bugs from an infested field of wheat at harvest-time was to pour a

narrow line of coal-tar along an especially prepared path at the edge of the field, with post-holes dug at intervals beside the line to trap and hold the bugs. This method, tho long in use, has certain serious handicaps, owing especially to the nature of the material used in making the impassable line; and I undertook to find some substance better suited to the purpose. Coal-tar answers admirably when first poured out, its adhesiveness and offensiveness preventing the passage of the bugs, which ordinarily do not even attempt to cross the line, and are immediately destroyed if they touch it. It is, however, so fluid at temperatures high enough to stimulate the chinch-bugs to escape from barren stubble fields that it sinks too quickly into the ground and must be often renewed at a large cost of labor and material. Even before it has thus disappeared, exposure to the air causes a film to form upon its surface so that it may be crossed by the bugs readily and without injury. Moreover, as it is a by-product of gas manufacture, its supply is limited and can not be increased to meet an increasing demand; and its price, already high for the purpose, is certain to rise when the demand becomes unusual.

EXPERIMENTS WITH COAL-TAR MIXTURES AND PETROLEUM PRODUCTS

Beginning in late August, 1910, an elaborate series of tests were made at Urbana of mixtures of coal-tar with various denser or powdered substances such as might give it greater body and so prevent its sinking too rapidly into the hot earth. Other experiments were made by mixing with it less volatile oils, resins, etc., which, uniting with coal-tar, in solution, might make the mixture more lasting when exposed to the heat. These various substances were tested in an electric oven the heat of which could be controlled, and in the open air out-of-doors. One hundred and thirty-five experiments of this character were run thru in the month of September with the result that a few of the substances tested seemed worthy of trial in the air under conditions as nearly like those of an Illinois summer as could be found at that late season. For this purpose Mr. Flint was sent to Brownsville, Texas, at the mouth of the Rio Grande River, with instructions to imitate on a small scale our standard field operations against the chinch-bug at harvest-time. The temperature, even thus far south, was, however, at the time of his visit (November 19 to December 3), too low to afford a fair test. The minimum readings in the open air ranged from 43 to 72 degrees in the shade and the maximum from 68 to 86 degrees, with a maximum temperature of 109 degrees F., at the surface of the soil in the sun. The substances whose efficiency was compared with respect to the time during which they would continue sticky enough to keep chinch-bugs from crossing them were coal-tar, 18-gravity oil, Heppe's flux oil, asphalt oil, and Superior oils Nos. 1 and 2. Of these, Heppe's flux oil, a petroleum product, proved to be from five to seven times as lasting as coal tar. As an average of eleven identical

tests, with temperatures ranging during each trial from 40 to 109 degrees, a narrow line of this oil poured upon the leveled earth of a back-furrow remained sufficiently sticky, without renewal, for twenty-one hours; and poured on inverted sod it continued effective in temperatures ranging from 40 to 103 degrees for thirty-eight and a half hours, as an average of six tests. On the other hand, nineteen tests with coal-tar applied to a back furrow gave an average of four hours and ten minutes with temperatures ranging from 40 to 100 degrees; and seven experiments with its application to sod gave an average duration of five hours.

The Petroleum Road Oils.—My attention being thus called to the possibility that petroleum residues might be found a more efficient and dependable means of defense than coal-tar, I began a correspondence with the vice-president of the Standard Oil Company, in Chicago, and the chief chemist of the refinery of that company, at Whiting, Ind., as a result of which they kindly had prepared for me samples of petroleum products similiar to road-oils, one of which seemed, on testing, to have the precise qualities sought for.

Four of the most promising of these substances were carefully tested in comparison with coal-tar at Urbana in April, 1911, by pouring them on very dry black soil in the insectary of my entomological office, recording temperatures, and noting the effects on the lines laid down. These were the Standard Oil Company's road oil No. 5 (containing 50 percent of asphaltic materials), their road oil No. 6 (containing 60 percent of asphaltic materials), and their 14-gravity and 16-gravity residuum oils. By experiments commenced at 2:30 p. m. April 19 and continued until 8 a. m. of April 22, it was found necessary to pour road oil No. 6 three times where nine pourings were necessary with No. 5, and 7 pourings with the 16-gravity oil. The temperatures of these days, as shown by thermometers placed on the soil in the sun, ranged from 68 degrees F. April 19 to 100 degrees April 21, and the exceptional reading of 125 degrees at 1 p. m. of April 20.

Another series, carried thru nearly two days, from 11 a. m. of April 25 to 7 a. m. of April 27, brought into comparison this No. 6 road oil, ordinary coal-tar, and 14-gravity oil. Where coal-tar required pouring thirteen times, once was sufficient with No. 6 road oil, and three times was necessary with 14-gravity oil. The results of these experiments led us to use road oil No. 6 in all our extensive operations in 1911. The summer of 1911 proved, however, to be excessively hot and dry, Sparta, for example, showing mean temperatures for May five degrees above normal, for June four and a half degrees, and for July one and three tenths degrees, with a maximum of 105 degrees in the shade for July 4; while the rainfall fell below normal, 2.44 inches in May, 2.58 inches in June, and 1.78 inches in July. On the extremely hot and very dry earth in the open sun the No. 6 road oil, altho preferable to coal-tar, became too fluid to serve the best pur-

pose; and experiments were begun in the fall of that year with a product of the same class containing 70 percent of asphalt materials, and known as "Road Oil No. 7." To secure an effective test of this oil in time for its use the following season, Mr. Flint was sent to Yuma, Arizona, where he made, October 9 to 15, a series of experiments similar to those of the preceding year, but under conditions much more favorable to a fair trial of the materials in hand. Only .12 of an inch of rain had fallen at Yuma for two and a half months, and the maximum daily temperatures at the time of his visit ranged from 80 to 96 degrees in the shade and the daily minimum from 41 to 66 degrees. The earth in the sun where the experiments were made warmed up to surface temperatures ranging from 100 to 120 degrees for several hours during the middle of each day.

To maintain an effective barrier for 6 days on a fairly level surface of very dry, sandy loam it was found necessary, under these conditions, to pour a line of coal-tar fourteen times, equal to two or three times a day; while road Oil No. 7 was poured but three times and road Oil No. 8 but once. The road oil last mentioned, containing 80 percent of asphaltic materials, had the disadvantage that it must be heated to run from the vessel used in pouring, and that it was not soft enough to hold the chinch-bugs at the lowest temperatures at which movements of escape might begin. On a surface with a slope of forty-five degrees, an effective barrier was kept up 4 days with road oil No. 7 by pouring it seven times, while it took thirteen applications of coal-tar to maintain an effective line under these conditions for two days only.

Several other experiments had indeed been made in September, 1911, by L. M. Smith, at Coulterville, Ill., bringing into comparison road oils Nos. 6 and 7 with coal-tar on the one hand, and with other products of the Standard Oil Company and the Barrett Manufacturing Co., of Chicago. To make these tests the stubble was scraped from the earth in a wheat field in a way to leave a hard smooth, but somewhat irregular surface, upon which the tars and oils were poured in a narrow line, such as one would use in making a barrier around a fields of infested wheat. These lines were all kept up for ten days, beginning September 5. The daytime temperatures varied from 78 degrees to 104 degrees F. by a thermometer placed upon the bare ground in the sun. Several rains fell during the period, some of them heavy enough to interrupt the experiment by covering the lines with dirt or by washing them away. Nevertheless, the results were significant and conclusive.

To maintain perfect lines it was found necessary to pour ordinary coal-tar forty-one times during the ten days, road oil No. 6 ten times, and road oil No. 7 but four, and these only because of the rains. Still heavier road-oils with 80 percent and 90 percent of asphaltic materials respectively (Nos. 8 and 9), required heating to make them fluid enough for pouring, No. 8 to 130 degrees and No. 9 to 160 degrees.

When so applied, No. 8 was somewhat more persistent than No. 7; but No. 9 became hard enough at 80 degrees to bear the weight of a chinch-bug, and it was not in perfect condition as a barrier until the soil temperature reached about 100 degrees. Most of the other mixtures tried were too fluid for the purpose, requiring from ten to forty-three applications in the ten days. They were also liable to form a film on the surface, enabling insects to cross even when the substance was still soft beneath.

As a result of these experiments, road oil No. 7 was the material mainly used in all our operations against the chinch-bug in 1912. (Figs. 5, 6, 7.) Especially recommended in a circular issued May 3, and used in our own field demonstrations, it was brought into the infested region in barrels by freight from Whiting in car-load lots and everywhere accomplished the purpose intended. It had, however, two rather serious disadvantages. It required for its successful use the careful preparation of a hard smooth path upon which the oil could be poured, and it was desirable that this pathway should be raised above the general surface to protect it as far as possible from dust and other objects likely to be blown upon it in a way to facilitate its passage by the chinch-bugs. In extremely hot, dry weather the task of preparing such a path in the hard dry earth was in some soils very difficult, and in some almost impracticable.

A more serious obstacle to success lay, however, in the fact that road oil of the quality needed in the chinch-bug work was not wanted or made for any other purpose, and that it must consequently be ordered some time in advance. Often the farmer would suddenly discover that his corn crop was endangered, was being already invaded, perhaps, from a neighboring field of wheat, only to find that he must wait a fortnight or more for relief; and by that time the mischief would be done. Furthermore, as the place of manufacture was distant a hundred and fifty to two hundred miles from the infested territory, delays in transportation were frequently serious, large shipments, altho called for in time, sometimes arriving after the emergency for which they had been ordered had mainly passed.

Failure of the 1913 Road Oil.—There was an oil refinery of large capacity at Wood River, in Madison county, within the infested territory, and it seemed possible to avoid the worst of the difficulties just mentioned by transferring the manufacture of road oil No. 7 from Whiting to that place; and in the spring of 1913 arrangements were made to this end. This step proved, however, most unfortunate, for reasons which we could not possibly have foreseen. The road oil furnished from the Wood River refinery, altho made by the same process and containing the same percentage of asphalt as that from Whiting, proved on delivery to have very different physical qualities, and to be inferior even to coal-tar for use against the chinch-bug. Where the Whiting oil would lie on a properly prepared surface as a viscid

ridge for two, three, or even four days, the Wood River oil would sink into the ground almost at once.

Later explanations from the responsible chemists brought out the fact that the two refineries were supplied with crude oil from different oil-fields, that furnished the Whiting refinery making a thick and viscid road oil and the other a comparatively fluid and penetrating one. Owing to this difference, indeed, the Wood River oil is much used for road-making, for which the oil must penetrate and consolidate, as it dries, the surface layers of earth on the road; while the Whiting product, lacking this quality of penetration, is virtually useless as a road oil. These facts were known, of course, to the Standard Oil officials, but their bearing on our work was not appreciated; and they were unknown to us until the almost total failure of field operations called for an explanation. The Oil Company furnishing this oil readily returned to purchasers all sums received for it, but this of course did not compensate for the losses due to dependence on it as a protection against the chinch-bug.

Crude Creosote as a Repellent.—By a lucky accident another substance had been found in 1912 nearly as effective against the chinch-bug as road oils of the best grade, costing more but requiring less labor to prepare a path, and obtainable at any time and in any quantity. A Montgomery county farmer, Mr. Henry Niehaus, who had exhausted his supply of coal-tar in trying to protect his corn against chinch-bugs coming from his wheat at harvest-time, was unable to get more at Litchfield, but was given for trial some oil of creosote from a barrel on hand in the general store of Bartling and Hussey, with the remark that it was the "worst-smelling stuff they had ever handled" and that "it ought to stop chinch-bugs, or anything else." Poured along the coal-tar lines, it proved as effective as the coal-tar, and was used for the rest of the season by Mr. Niehaus and by five of his neighbors also. The facts coming to the knowledge of Mr. Flint (my field assistant for that part of the state) in May, 1913, experiments were at once made which showed that the chinch-bugs were strongly held in check by the odorous vapors given off by the creosote, and not by any caustic or other physical property. Indeed bugs surrounded by a circular belt of creosote on the ground would cross it quickly when excited and without the slightest injury; but if it were placed as a line across their path they would stop short of its margin and turn in another direction. Enough was done with this substance during the latter part of the season of 1913 to warrant us in giving it equal standing with the petroleum road-oils—preferable indeed in some respects—and this was the material with which the final, most extensive, and most successful campaign of our chinch-bug period was mainly made in 1914.

The fluid creosote did not lie upon the surface but sank readily into the ground, slowly evaporating on exposure, and it was necessary to

renew it only when the odor became too faint to repel the bugs. On this account it was only necessary to prepare a fairly level strip on which it might be poured, careful smoothing and firming of the path being unessential.

That it is the odorous vapor of creosote which prevents the passage of the bugs is illustrated not only by our field observations of the reluctance of the insects to approach the creosote strip, but also by an experiment made by Mr. Flint at Springfield in December, 1913. Fifty adult chinch-bugs were confined in an open box, 19x9 inches and 1½ inches deep, by chalking the upper edges of the sides. After they had settled quietly, various strong-smelling substances were introduced among them. Tested in this way the chinch-bugs paid no attention to sulphur or asafetida, and but little to wood soaked with chlorhydric acid, but they immediately scattered when exposed to the vapors of creosote, none of them coming within two inches of the object for the next four hours during which they were watched, and still keeping at a distance of an inch from it five hours later. Formic acid was almost equally repellant.

Altho a creosote line was not so complete a protection as one of road oil, a small percentage of the chinch-bugs filtering past it even when it was properly laid and carefully supervised, yet the number was never large enough to do noticeable harm to corn; while in one respect the creosote barrier was better than the road oils since its odor was not affected by dust, straws, or other rubbish blown across it, such as would often cover or bridge a road oil line in a way to allow the bugs to pass it readily. The efficiency of an old creosote barrier might even be increased by a shower of rain sufficient to destroy that of a road-oil line by washing parts of it away or covering them with dirt. The creosote, being lighter than water, rose to the surface when the ground was wet, and its efficiency was thus increased, rather than lessened, by the rain.

The average cost of the creosote used to keep up an effective barrier during the chinch-bug migration season of 1914 was $16.50 for each mile of the line. We have definite information of the use of 1840 barrels this year, at a usual cost of $7 to $10 a barrel according to quantity and quality ordered.

EXPERIMENTS WITH INSECTICIDE SPRAYS

Kerosene Emulsion.—As a secondary method of defense against chinch-bugs, very useful under certain conditions and in certain emergencies, spraying with insecticides which kill by contact is especially to be advised. That a 5-percent kerosene emulsion will kill the chinch-bugs at a reasonable expense was a fact first established by the writer in 1882; but this material has the disadvantage that its correct preparation requires special care and considerable labor, and that if used on young corn it must be so applied as not to lodge in the "heart"

or curl of leaves at the tip of the plant, since otherwise it will kill the corn. By field experiments made with it in August, 1911, from 60 to 86 percent of the bugs were killed with a 4-percent solution on corn about two feet high. It was applied with a portable "automatic" pump which forced the fluid out by air-pressure in a small solid stream and not in a spray. The emulsion was made by dissolving eight ounces of soap, by boiling, in a gallon of water, adding two gallons of kerosene to the hot solution and pumping the mixture back into itself in a forcible stream for several minutes, until it made a uniform, cream-like mixture from which the oil would not separate on standing. This gallon of "stock emulsion" was diluted by adding to it fifteen and a half gallons of water to make a mixture containing 4 percent of kerosene.

Easier methods of preparing the kerosene-soap emulsion and simpler methods of applying it to the corn were found unsatisfactory, sometimes because comparatively few of the bugs were killed, sometimes because the corn was injured, and sometimes for both of these reasons together.

Tobacco Preparations.—In 1910, experiments made in southern Illinois by Mr. L. M. Smith, in charge of our chinch-bug work in that part of the state that year, showed that a spray of tobacco extract known as "Black Leaf 40" was much more easily prepared than the kerosene emulsion, was more deadly to the chinch-bugs, and was not at all injurious to the plants to which it was applied. Precise tests of this insecticide were made by Mr. Flint at Plainview in August, 1911. In the first of these a half ounce of the tobacco extract was diluted with a gallon of water in which half an ounce of soap had been dissolved, and the solution was applied in a small straight stream, by means of a portable automatic pump, to infested corn from twenty to forty inches high. Twenty-four hours later twenty hills of this corn taken at random were carefully examined, with the result that on three of the hills 75 percent of the bugs were dead, and on seventeen hills 90 percent, making an average of 88.5 percent for the whole, while the corn was not injured in the least. In four similar experiments the Black Leaf 40 was reduced to a fourth of an ounce to the gallon of water, and the soap was increased to one and a half ounces. In these the percentages of bugs killed ranged from 74 to 85.5 and in still another experiment, with half an ounce of Black Leaf 40 and half an ounce of soap, the number of chinch-bugs killed on the different hills was estimated at 75 to 90 percent.

The cost of the materials necessary for a thoro treatment of infested corn varies of course with the size of the plants. In corn six feet high it averaged $5 per acre; in that six to fourteen inches high it averaged $1.30 per acre. With the small portable spraying apparatus used in these experiments it would have taken one man eighteen

hours to spray an acre of corn six feet high, or four and a half hours per acre of corn averaging ten inches high.

The profitable use of these tobacco sprays is practically limited to fields of large corn the outer rows of which have become heavily infested by chinch-bugs, which thru neglect or accident, have entered the corn from adjoining fields of wheat in numbers sufficient if left to themselves to destroy the entire field; and to fields of young corn which have become infested by chinch-bugs of the hibernating generation in early spring. Many instances of this latter kind occurred in 1912 where farmers plowed up in spring heavily infested wheat because of winter-killing or injury by the Hessian fly, planting corn at once on the same ground. The chinch-bugs already in the field infested the corn as soon as it came up, and laid their eggs there for the first new generation of the year; and these presently appeared in numbers to destroy the corn completely when it was only a few inches high. A general spraying of this young corn with Black Leaf 40, ¼ ounce to the gallon, saved the crop in many fields at a comparatively trifling expense.

Other corn-fields became infested in the same way by reason of a cool spring which produced a heavy growth of wild grasses in the old corn-fields before they were plowed. The chinch-bugs laid their eggs on these grasses in immense numbers, and when the fields were plowed and planted to corn the young bugs destroyed the corn plants except where effective spraying was done.

Insecticide Sprays in Wheat Fields.—In the latter half of April, 1912, a number of field experiments were made with sprays applied to chinch-bugs in wheat fields with a view to learning whether it might be feasible and profitable to destroy the bugs at that season of the year after they had gone into the wheat, particularly where, as is often the case, certain patches of the wheat were much more heavily infested than the remainder. To secure precise results chinch-bugs were taken from their winter shelter, usually bunch-grass, and placed in plots of wheat a yard square surrounded by a road-oil line to prevent the escape of the insects. The wheat was three or four inches high at the time.

In each of three such experiments, twenty bugs, taken from the plot after it had been thoroly sprayed, were placed in a cardboard box, and left there for twenty-four hours. In one where a sixth of an ounce of Black Leaf 40 was used to the gallon of water, eight of the twenty in the box were dead after twenty-four hours, and six others were so affected that they were not able to crawl. They doubtless died later from the effects of the treatment. In still another experiment, where one fourth of an ounce of the tobacco extract was used, all of the twenty bugs were dead after twenty-four hours except two which could still make slight movements of the legs; and in a third experiment of the same character, three of the twenty were able to crawl and

three others made slight movements of the legs, the remainder being dead. In all these plots there were many dead bugs on the ground where the wheat had been sprayed. The same was true of other experiments made in the same way, in which none of the bugs were separated for counting.

In another lot of fifteen experiments with Black Leaf 40, chinch-bugs collected in hibernation were placed on dry cloths in lots of twenty, sprayed with tobacco solution, and transferred at once to dry cardboard boxes. Examined from twenty-four to forty-eight hours afterwards 71 percent of the bugs so handled were found to be dead.

Additional experiments of the same general description, made with kerosene emulsion containing 5 and 10 percent of kerosene, applied to chinch-bugs in the wheat, showed that this insecticide was practically without effect under these conditions. In three such experiments only three bugs were killed. That this was due in part to the conditions in the field is shown by the different result of tests made by spraying kerosene emulsion upon chinch-bugs placed on a dry cloth and transferring them to cardboard boxes. In this case 54 percent of the bugs were killed as an average of eight experiments. Similar trials were made of scalecide at various strengths, from 1 percent to 10 percent in water, with practically no effect on the bugs. Emulsions of gasoline and soap containing 5 and 10 percent of gasoline proved similarly useless, as did also solutions of iron sulphate in proportions of one pound and two pounds to the gallon of water.

As the tobacco extracts prepared by manufacturing companies are rather expensive, it was thought possible that cheaper and equally effective sprays might be made direct from the wastes of tobacco factories, and a few tests of this supposition were also made in 1911.

In the best of these three ounces of cigar clippings were boiled in a gallon of water for half an hour and diluted with twice as much water in which an ounce of soap to the gallon had been dissolved by boiling. This mixture was applied to infested corn with a portable automatic sprayer which discharged a small straight stream. The result as tested by a careful examination of the sprayed hills of corn twenty-four hours later showed that from 21 to 48 percent of the bugs had been killed.

Experiments with Solutions of Soap.—In all these mixtures thus far described, whether made with kerosene or tobacco, small amounts of soap were used either to produce an emulsion or to increase the spreading and penetrating power of the tobacco solution. To distinguish the insecticide properties of these ingredients experiments were made with soap solutions alone, with results so unexpectedly favorable that an elaborate series of tests were made at Springfield during the winter of 1912–13 with a large number of different brands of soap obtainable on the ordinary market. In each of these experiments a number of chinch-bugs collected from their hibernating quarters and

brought into the laboratory were placed on dry paper, thoroly sprayed, and transferred at once to dry paper bags in which they were left for twenty-four hours at a temperature of about 65 degrees F. From the following table it will be seen that the different brands of soap differed quite remarkably in their apparent insecticide power, the home-made lye soap as tested in seven experiments (88.6 percent killed) equaling the solutions of Black Leaf 40, while Peosta soap, as tested in ten experiments, killed about as many chinch-bugs as the best of our home-made infusions of cigar clippings. The lowest ratio of chinch-bugs killed was 40.8 percent as the average of eleven experiments with Lenox soap.

For large-scale operations the commercial extracts of tobacco, used as already described, are undoubtedly to be preferred as the most effective and reliable; but for emergency work soap solutions will serve an excellent purpose. One hundred and sixty-seven experiments made with fourteen brands of soap gave an average of 66 percent of the insects killed by this means.

INSECTICIDE TESTS OF SOAP SOLUTIONS MADE BY W. P. FLINT, AT SPRINGFIELD, DURING THE WINTER OF 1912–'13

Brands of soap	No. of experiments	No. of chinch-bugs used	Percentage of chinch-bugs killed
Home-made lye	7	70	88.6
Grandpa's Tar	11	110	77.3
Rub-no-more	11	110	73.6
Swift's Borax	8	143	73.4
Pyles Pearline	17	230	73.0
Brown's Pine Tar	8	109	70.6
Home-made Rosin	15	157	70.0
German mottled	9	100	67.0
Topsy Tar	17	132	64.3
Fels Naphtha	4	62	61.0
Ivory	15	190	59.2
American Family	24	250	56.4
Peosta	10	100	48.0
Lenox	11	120	40.8
	167	1,883	Av., 66.0

As a test of the practical usefulness of the soap sprays applied to entire fields of well-grown corn, an acre and a half of heavily infested corn was treated at Plainview August 2, 1913, when the plants were four to six feet high. Unfortunately the soap selected was one of the brands which experiments had shown to be of rather low efficiency. Twelve bars of American Family Soap, each weighing ten ounces, were dissolved in forty gallons of hard water (3 ounces to the gallon), and the solution was applied to the corn by means of a barrel pump set on a drag and drawn by one horse between the rows. Two rows of corn were sprayed at each round of the field, one man driving the horse and working the pump, and another handling the Bordeaux noz-

zle. The thoro treatment of this acre and a half of corn required three hundred and twenty gallons of spray, costing thirty cents an acre for the soap and the labor of two men and a horse for a day and a half. An examination of the treated corn three days later showed that about 75 percent of the bugs had been killed—apparently all that were actually reached by the fluid. Those alive had evidently been protected by the boots of the leaves behind which they were hidden. The corn showed nowhere any trace of injury.

FIELD EXPERIMENTS AND DEMONSTRATION FIELDS

Beginning in June, 1910, wheat fields heavily infested by chinch-bugs and so situated as to be readily accessible to the farmers of the vicinity were secured for experiments, and practical demonstrations were made of the trap and barrier method, at first with coal-tar, later with the two road-oils Nos. 6 and 7, and finally with crude creosote.

Demonstrations with Coal-tar in 1910.—A demonstration field near Oakdale, in Washington county, gives us a good illustration of the value of this method, with coal-tar as the medium. This was a twenty-acre field of wheat sufficiently infested by both Hessian fly and chinch-bugs to make it doubtful whether the crop would repay the harvesting expenses. A barrier was made June 22, 1910, by plowing, smoothing, and compacting a ridge on all sides of this field, digging post-holes to a depth of eighteen inches at the edge of the ridge, at intervals of twenty-five, fifty, and a hundred feet on different sides of the field, and pouring a narrow line of coal-tar on the dry ground along the center of the ridge in a way to touch each post-hole on the side farthest from the field. This barrier, three quarters of a mile in length, was kept up for eleven days, after which time so few bugs were left in the wheat as to make further work unnecessary. The chinch-bugs accumulating in the post-hole traps were killed with kerosene poured into the holes, followed by sufficient water to float the oil to the top of the mass.

The coal-tar sank so readily into the dry and dusty earth on the first day that three applications were necessary, but two a day thereafter served the purpose, one made about seven in the morning and the other at 2:30 in the afternoon. These times were selected in order to oppose a line of fresh tar to the chinch-bug during both morning and afternoon movements. In the hot clear weather of these days the chinch-bugs moved from 7 to 10 in the morning, but from 10:30 to 2 in the afternoon there were practically none in motion except in shaded places. The principal movement of the day, however, came, as a rule, between 3:30 and 5:30 in the afternoon.

Converting our data of cost of operation into expense per mile of barrier—a line sufficient, that is, to surround a 40-acre field—reckoning the farm labor used at $2 a day and the coal tar at the market price of that season—$2.50 a barrel and freight from the nearest point—we have a total cost of $23.41 per mile for the whole period of

eleven days, of which $13.33 was the value of the labor and $10.08 the cost of the tar used. This was at the rate of $2.13 per mile for each day of the time during which the barrier was kept up, of which $1.21 per mile per day was the value of the labor and ninety-two cents the cost of the tar used.

An attempt was made to measure the bugs caught in the post-holes, and 3½ bushels were actually collected; but heavy rains on July 2, 3, and 4 filled the holes with mud and water, and made further measurement impracticable. On the sides of the field where the post-hole traps were a hundred feet apart, many of the bugs attempting to escape failed to find them and were either killed by the hot dust of the barrier ridge or entangled in the coal-tar line and thus escaped our measurement. If we take the 3½ bushels as the total yield of the operation, the cost was $5.02 per bushel of chinch-bugs, of which $2.16 was for coal-tar and $2.86 for labor. As there are about 8,500,000 chinch-bugs to the bushel at this time of the year, this was at the rate of nearly 17,000 dead chinch-bugs for each cent of the expense. When we take into account the fact that these were all bugs of the first generation of the year, and that if allowed to escape they would presently have bred a second generation to infest the corn at a rate, according to previous observations and estimates, of about 100 to 1, it is easily seen that this was an immensely profitable operation to the community as a whole and immediately useful also to the farmer concerned, as saving his corn from destruction where it lay beside wheat.

In a field near Patoka, in Marion county, a barrier seventy rods in length was maintained for twenty-seven days, June 28 to July 24, between a field of infested wheat and one of corn immediately adjoining. The difference in time during which the barrier was maintained in this field and in that at Oakdale was due to the quick destruction of the wheat in the Oakdale field by insect infestation which compelled a prompt escape of the bugs to obtain food. In this Patoka field it was necessary to renew the tar-line thirty-seven times and to use sixty-five gallons of coal-tar in so doing. The labor in this case amounted to $4.80 and the cost of the tar was $4.04,—a total expense per mile of barrier of $40.42, of which the labor item would be $21.95 and that for coal-tar, $18.47. This is equivalent to $1.49 per mile for each day during which the barrier was maintained; but of this sum only sixty-eight cents per day was for the cost of materials.

The third demonstration field of this season was near Dubois, in Washington county, where a tar line a hundred and twenty-eight rods in length was maintained for nineteen days, June 21 to July 9. In this case tar was poured upon the barrier ridge thirty-eight times—an average of twice a day—at a cost of $15.77, of which $6.80 was for labor and $8.97 for tar. The latter sum was regarded by the field superintendent as excessive, the tar having been wasted by too liberal use in pouring. This was a total expense for the season of $39.43 per mile

of barrier, of which $17 was for labor and $22.43 for tar. Or, otherwise stated, the cost of the operation was $2.07 per mile per day, of which ninety cents per mile was for labor and $1.17 for tar.

It is a fair general statement of the cost of the coal-tar barrier under the conditions of 1910 to say that it was equivalent to $1.50 to $2 a mile per day, and that the cost of materials was approximately 45 percent of the whole, the remainder being an allowance for the labor of horse and man.

Demonstrations with Road Oil No. 6 in 1911.—The events of 1910 having shown us that we were undoubtedly at the beginning of one of the periodical uprisings of the chinch-bugs, tremendously destructive to Illinois agriculture, preparations were made for a general campaign of education, demonstration, and organized defense. Thoro scouting in winter and spring, by my field assistants having defined the area likely to be heavily infested, this was divided into five districts, an assistant was assigned to each, and a superintendent of operations and supply was engaged to take general charge. Each of the assistants was provided with a motorcycle and the superintendent with an automobile roadster, to enable them to cover a large territory as rapidly as possible when the brief season of activity should arrive. As our road oil No. 6 was virtually unknown to the farmers, and as the source of supply was about two hundred and fifty miles from the place of demand, it was thought best to make sure of a sufficient quantity at hand for the beginning of the campaign and to meet unexpected emergencies, and three car-loads in barrels, were ordered by the office to be shipped to Centralia. From here it was sent to sales agents at various towns thruout the infested region under an arrangement by which the oil, in barrels, was furnished to farmers at first cost with the freight charge added. The salesmen paid the company direct for the amounts handled by them, and my office paid the salesmen a small commission for their services. Any oil left on their hands at the close of the season was taken over by the office for use the following year. In this way supplies were made immediately accessible to the farmers at cost, and the dealers were protected from loss with very little use of public funds. Except for this emergency stock, the supply of road oil was left to such agents as the farmers themselves had interested, with our assistance, in various communities. Often this community service was done without compensation by some business man acting as purchasing and distributing agent for an organized group of farmers, or, in a few cases, for all comers in his county. Many public meetings had been held for this purpose with the valuable aid of business men's associations, the farmers' institute officers in the various counties, the local newspapers, and the like, and circulars of information, warning, and advice had been distributed in editions of many thousands thruout the endangered area. The fact was commonly realized by business men generally that the suppression of the chinch-

bug outbreak was a community problem in which all were alike, tho unequally, interested.

Demonstration fields, on which the precise best method of preparing and caring for a chinch-bug barrier was practically illustrated, were, of course, an important feature in our program, and a number of such fields were selected by each field assistant, arrangements being made in advance with the owners for their proper management. These demonstration fields were in the neighborhood of the following eighteen towns: Edwardsville and Highland, in Madison county; Vandalia, Hagarstown, Shobonier, and Vera, in Fayette county; Fairman, Vernon, Patoka, and Selmaville, in Marion county; Albers, Germantown, and Bartelso, in Clinton; Ashley, Nashville, Oakdale, and Caspars, in Washington county, and Coulterville, in Randolph county.

The season of 1911 was a very trying one for the road-oil line, the weather being excessively hot and the ground extremely dry, the months of May and June in the chinch-bug area averaging 5 degrees and 4.1 degrees respectively above the normal, and June and July temperatures rising repeatedly to 100 degrees or more in the shade—to 105 degrees at Sparta and Duquoin, for example, on July 4. The June rainfall was less than half the normal, and that for May and July was only a third the normal for this area. The soil in the sun was, of course, very much hotter—so hot as to make even road oil No. 6 sink into the dry earth much too quickly, requiring its frequent renewal at an increased expense for labor and materials except where the precaution had been taken to make a shallow groove for the oils down the middle of the ridge or path. For these reasons the cost of operations on the experimental and demonstration fields ran much above that of the preceding year, from fifty cents to $2.00 per mile per day for the road oil used, and from ninety cents to $3.50 per mile per day for labor. Even at these rates, however, the work done with the road oils saved so many acres of corn and oats that it was commonly regarded to have returned to the farmers many times its cost. Nevertheless, the experience of the season led us to substitute road oil No. 7 for No. 6 the following year, and in this we had what was virtually a perfect material for the purpose.

Road-oil No. 7 in 1912.—The greater part of the area infested in 1912 having been already covered by our demonstrations of the previous year, the use of new fields was secured for this purpose only in the newly invaded territory. These were all, however, successful and useful. At Reno, Bond county, for example, a tract of forty-seven acres was selected in which there were fourteen acres of rye, thirteen acres of wheat (both the foregoing in young timothy also), twelve and a half acres more of wheat which was so infested by chinch-bugs that it was plowed up and sown to cow-peas, and seven and a half acres in oats. This tract, with corn on three sides and a part of the fourth, was completely surrounded by a back-furrow and coal-tar barrier,

June 27, and the work was continued with road oil No. 7. The presence of fresh timothy in half the field so held the chinch-bugs back in the stubble that the lines were kept up for twenty-six days, at the following expense:

Plowing the ridge (1½ days' labor with man and team)		$ 4.50
135 hours' labor pouring oil and tar		27.00
3 barrels road oil at $3.50		10.50
1 barrel coal-tar, at $4		4.00
Total for materials	$14.50	
Total for labor	31.50	
		$46.00
Cost per day per mile:		
Materials		.56
Labor		1.21
		$ 1.77

The diminished cost as compared with that of 1911 was due in part to the substitution of road oil No. 7 for No. 6 and in part to the less trying character of the season. While the average mean temperature for June and July in the chinch-bug area was nearly as high as in 1911, there were no records of as much as 100 degrees in the shade in either month, and the rainfall of June and July was *above* the normal by .58 of an inch for June and 1.68 inches for July instead of 2.4 inches and 2.16 inches below the normal in the year preceding. The thicker road-oil lay much longer on the moister earth, with a resultant saving in both labor and material. On the other hand, timely rains supported infested corn against the drain of chinch-bug injury so that even unprotected fields suffered much less than in 1911.

Altho there were no experimental or demonstration fields in Macoupin county in 1912, Mr. Flint's statement of farmers' operations may be taken as a virtual substitute. Forty barrels of road oil No. 7 and about twenty-five barrels of coal-tar were used in the vicinity of Carlinville, Plainview, and Bunker Hill. The road oil No. 7 gave general satisfaction, and was evidently about as thick a substance of its kind as could be used to advantage. It was repeatedly noticed, indeed, that where No. 8 was used it could be crossed by chinch-bugs in the morning and the evening, when the nights were cool. It took from four to six times as much coal-tar as road oil No. 7 to keep up a given length of line. The ground was usually prepared for the road-oil line by plowing a very shallow furrow around the field and trimming this with a hoe to leave a hard level surface. The very best barrier, however, was one prepared by dragging a heavy plank in the edge of a corn field to make a hard smooth surface, and then driving an empty wagon along in such a way that one of the wheels made a slight groove down the center of this path. Road oil poured in this groove made a line which lasted for twenty days with no renewal except to be touched up here and there occasionally where there were small breaks.

The average cost of operation during this season for ten fields on different farms in Madison county was collected by Mr. Flint, from whose notes these data are abstracted. The road oil used on these farms averaged 4.4 barrels to the mile of line for a period of fourteen days—a cost of $7 per mile for the fortnight, or fifty cents per mile per day. The labor cost for this period was $8.40 a mile, making a total average expense of $1.10 per day per mile. By the maintenance of such barriers, half a mile of oil-line saved, in several cases, from ten to thirty acres of corn from certain destruction; and in one instance sixty acres of corn destroyed by chinch-bugs could easily have been saved by a line less than half a mile in length.

A more comprehensive statement of the general outcome of the 1912 campaign is contained in an article written by Prof. F. W. Scott, of the department of journalism in the University of Illinois, who made a trip of inspection thru the infested territory in July, 1912, to interview farmers, examine fields, and report his own unbiased observations on the methods and results of the work. "The most satisfactory results," he says, "considering both cost and protection, have been obtained from a line made of No. 7 road oil, which, when properly applied, caught all the crawling bugs and was easy to maintain. Those who followed the directions as given in the Entomologist's spring circular of this year [1912] found that the road oil needed renewal but once in two or three days after the first two applications, and some lines were found to be in perfectly good condition two weeks after the final renewal. Coal-tar lines, on the other hand, had to be renewed once or twice every day, and were of course more costly both in labor and in actual outlay for material."

THE FINAL CAMPAIGN (1914)

The lamentable failure of the road oil furnished from Wood River in 1913, together with continued and extraordinary drouth in the chinch-bug area, tended strongly to discourage many who had made a determined fight during two or three years for the salvation of their crops. From April to August, 1913, inclusive, the daily mean temperatures aggregated nearly 2000° F. above the normal for this region, and the total rainfall for these same months was deficient about eight and a half inches. Furthermore, the partial and very imperfect way in which the chinch-bugs had been met and disposed of at harvest-time, had left a vast and increasing horde of them to overwhelm crops the following year; and the plague seemed to be increasing in virulence and destructiveness, notwithstanding all that had been done for its control. There was, consequently, a diminished disposition in 1914 to renew the contest in the counties which had been longest infested; but there was a considerable territory invaded or seriously threatened by the chinch-bug in the spring of this year which

had never been covered by our operations, and to this we consequently gave principal attention. Our most important spring preparations covered all or the greater parts of the counties of Pike, Scott, Morgan, Sangamon, Christian, Green, and Fayette, and much of the counties of Jersey, Madison, Macoupin, Bond, St. Clair, Montgomery, and Shelby. By all the agencies and devices which we had found useful in previous years, the people of this territory were notified, advised, instructed, and assisted. Public meetings were held at which the facts were set forth and the plan of operations was outlined; leading farmers, grain dealers, and others influential and widely known among the farming population were interviewed; illustrated posters were put up in post-offices and other places of general resort; and many thousand circulars were distributed by mail.

At the end of the season data were collected for a careful estimate of the results of the work. By a general inquiry made of those who had handled supplies in the counties of Montgomery, Christian, Sangamon, Menard, Macon, Morgan, Scott, Pike, Adams, Jersey, Macoupin, Greene, and Madison, it was learned that not less than 2000 barrels of creosote and 1000 barrels of coal-tar had been used, together with considerable quantities of kerosene and salt. Further inquiry enabled us to learn the average amounts of these substances actually used per mile of barrier, and by this means to ascertain the total length of barrier made and maintained for the season, and the total cost of the same. All uncertain items of the computation were estimated at the lowest reasonable figures. We were thus assured that at least fifteen hundred miles of barrier had been kept up in these counties between fields of infested wheat and adjacent fields of corn, at a total cost, for both materials and labor, of not more than $40,500.

To learn what area of corn was actually protected by these barrier lines, it was necessary to know the size of an average central Illinois corn-field. Fortunately, a series of observations made for me by two assistants engaged in a survey of the bird life of the state in 1907, gave me this information. In crossing the state from Wabash to Quincy, they traveled 71.87 miles through 362 corn fields, an average of 63.53 rods for each field. Virtually all central Illinois corn-fields being rectangular, the average form of a sufficient number is that of a square, and the average size by the above data is 25.2 acres. In other words, our fifteen hundred miles of chinch-bug barrier had protected from invasion the equivalent of a belt of corn fields 63.5 rods wide and fifteen hundred miles long—an area of 190,590 acres. The average yield of corn per acre in ten central Illinois counties not infested by chinch-bugs in 1914 was 30.8 bushels. It was the best judgment of my field assistants, supported by that of well-informed farmers, that 25 bushels per acre was a very moderate estimate for the yield of the protected corn-fields, and it was also the general opinion that at least a fourth of this yield was due to measures of protection

against injury by chinch-bugs. At these rates the total product of the protected area was 4,764,750 bushels, and the saving by protection was 1,191,187 bushels, worth, at 60 cents a bushel, the ordinary price for the season, $714,712. As the cost of protection was $40,500, the net profit for the total operation was $674,212, a ratio of 1665 percent on the investment.

This result was obtained by making barriers, as a rule, along only one side of infested wheat-fields. If each such field had been wholly surrounded, the expense, of course, would have been four times as great, or approximately $162,000, but the net profit even then would have been 342 percent on the cost of labor and materials. Indeed, if the like had been done by every owner of a badly infested wheat-field in this area, the total profit would have been much increased, since both corn and oats would have been protected, not only against direct invasion from infested wheat but against a general infestation following when the chinch-bugs allowed to escape from the wheat came to maturity and scattered on the wing. These figures show not only the great advantage of wholesale operations against the chinch-bug at harvest-time, but the essential reasonableness of the requirement that all dangerously infested fields of small grains shall be so handled by their owners that insects shall not escape from them to the injury of the owner himself and of his entire community. I am strongly of the opinion that if we had been in a position to make a requirement of this kind in 1910, and if we had then known all that we have now learned concerning the best methods and materials for use against the chinch-bug at harvest-time, it would have been quite possible so to reduce the numbers of chinch-bugs that year that there would have been no appreciable overflow the following year, and hence no northward expansion of the area of infestation. In other words, it seems to me quite possible to throttle a chinch-bug outbreak in this state in the beginning by active scouting in fall and spring to determine its limits and to locate dangerously infested fields, and by well-organized, prompt, general, and concerted action, especially with barriers and lines of post-hole traps around infested fields of small grains, with the addition of insecticide sprays wherever special conditions call for their use.

THE LEGISLATIVE REMEDY

The statement has been repeatedly made in the foregoing discussion that we have found it quite impossible to induce the average farmer, or even the farmer of the highest grade, to do his best at harvest-time for the destruction of *all* the chinch-bugs escaping from his fields of wheat; but unless this is done it will be forever impossible to put a controlling check upon chinch-bug uprisings. The fatal difficulty lies in the fact, obvious to every one, that the individual farmer will not incur the trouble and expense of destroying his chinch-bugs for the

benefit of his community unless he knows that the other members of the community will do the same.

The situation is essentially like that presented several years ago when the prosperity of fruit culture—its profitable continuance even —were threatened by an invasion by a destructive foreign insect known as the San Jose scale. This emergency was met in Illinois and in most other American states by making it the duty of all growers of horticultural products to keep their premises free from insect and fungus pests of every description which are liable to spread to the property of others, and enforcing this requirement by appropriate penalties. Legislation of this character has not only put it within the power and made it the duty of some state official—in Illinois the State Entomologist—to protect endangered property—by legal process if necessary—but it has acted powerfully to impress the public concerned with a sense of their duty in the premises, and through the resulting publications of the entomologist's office, the agricultural papers, and the like, to instruct the people thoroly in a whole class of subjects of which they would otherwise have remained in ignorance to their own great loss and to that of their communities and of the country at large.

Influenced by these considerations I sent out, in January, 1915, the following letter to twenty-nine prominent farmers residing in districts badly injured by the chinch-bug the preceding year, and to three other persons officially cognizant of the facts.

"An outbreak of the chinch-bug in Illinois, which began in a few southwestern counties in 1910, has now reached a crisis which forcibly illustrates our helplessness against a considerable class of destructive raids of the insect pests of agriculture because we are not able to secure, by any means now available, sufficiently general action by farmers concerned to get the benefit of cooperative measures. The actual loss last year (1914) in corn alone, due to the chinch-bug, amounted, for Illinois, to not less than $2,700,000,* and there is at present a prospect of a much more extensive infestation during 1915.

"The chinch-bug breeds, as you doubtless know, in two generations, the first mainly in wheat and the second mainly in corn. The first generation, hatching from eggs laid in spring, has not yet got its wings at the time of the wheat harvest, and hence must leave the stubble fields on foot to find fresh pastures in corn, oats, and forage grasses. It can be stopped, trapped, and destroyed by barriers and traps laid down at the borders of the infested wheat-fields at a usual cost, for the season, of less than ten dollars a mile in money and an additional ten to twenty dollars a mile in farm labor; and every insect so disposed of at this time is ordinarily equivalent to a hundred times as many of the next generation which would hatch from eggs laid in the corn.

*This estimate was far too small. The actual loss was more than $5,000,000.

"We have succeeded in the past year in inducing very many farmers to protect their corn against direct invasion from infested wheat-fields (where corn and wheat lie side by side), by placing and maintaining one of the trap and barrier lines between the corn and the wheat at harvest-time, with the result that, in thirteen central Illinois counties, corn worth $804,000* was saved at an expense of $40,500 to the farmers for materials and labor, and of $1933 to the State. The average farmer, however, will not entirely surround an infested wheat-field in a way to capture *all* its insect inhabitants, especially for the reason that this would be of no appreciable benefit to himself unless his neighbors generally do the same; and if he has no corn or oats beside his wheat, he will do nothing at all. The consequence is that the bugs move out of the infested wheat in at least three directions, even if they are headed off and trapped in one; and those escaping presently get their full growth, scatter everywhere on the wing, infest the corn and other crops of the whole country-side, and there feed and lay their eggs almost as if nothing at all had been done. Persons able and ready to destroy all the bugs of the first generation bred in their own fields, will not do so when they know that their neighbors are breeding vast hordes of them and allowing them to escape to destroy everything a little later.

"We are thus compelled to seek means of securing general action such as will give every person concerned a reasonable assurance that all others will do their duty by the community. To this end it has been suggested that the legislature be asked to pass a law making it the duty of every person having a field of small grain dangerously infested by chinch-bugs to take the measures necessary to prevent their escape to the injury of the property of others, *with a proviso that this law shall take effect only when and where a proclamation by the Governor of the State may direct.* The chinch-bug is but one of several insect pests of the farm whose control and destruction present the same practical problem, and any such law should be drawn in terms, consequently, to apply to all similar cases. The principle involved, I may say, is already well recognized in our various state quarantine laws, and especially in our state law intended to operate against the spread of the San Jose scale and other dangerous and destructive pests of horticulture.

"I should be much pleased to have your opinion of the desirability of such legislation at the present time, and as full an expression of your views upon the situation generally as you may be willing to give."

Sixteen replies to these letters were received, ten favorable to the proposed legislation, three favorable to the principle but doubtful of its practicability, and three simply uncertain or non-committal. As only a third of those addressed expressed a positively favorable opin-

*This should have been $715,000.

ion, and as there was not sufficient time—the legislature being already in session—for a campaign of explanation and argument, it seemed best to lay the project aside for the time, and to bring it forward, as I am now doing, as a sequel to a full description of the conditions which it is proposed to remedy.

SUMMARY

A destructive outbreak of the chinch-bug, the first beginnings of which were seen in Illinois in the fall of 1909, continued with growing intensity and gradually widening area until the spring of 1915, when it suddenly collapsed.

A careful computation of losses resulting, based upon a comparison of crop yields and crop conditions in seventeen infested and seventeen uninfested counties, shows that the yield of corn, wheat, and oats in these infested counties was diminished by chinch-bug infestation in the year 1914 as follows: corn, $5,045,874; wheat, $1,356,039; oats, $41,071—a total of $6,442,984. Taking further account of losses in six other counties in 1914,, and in the five other years of the period of the outbreak, $13,000,000 is arrived at as the lowest reasonable estimate of the total immediate loss in these three staple crops. Secondary effects of the outbreak are illustrated by a comparison of statistics of live-stock production in four infested and four uninfested counties, showing that beef and dairy cattle of the four infested counties fell off in numbers to a value of nearly half a million dollars, as a plain consequence of the destruction of crops by chinch-bugs.

An analysis of the weather and other conditions for several years in the region where the chinch-bug outbreak began, points to a conclusion that the immediate cause of its beginning was unusually hot midsummer weather, with no excessive rainfall, occurring in a region in which the food plants occupied a relatively large area, with winter wheat in especially large ratio. There was also convincing evidence that the extension of the outbreak from the area occupied in 1910 was in the nature of an overflow from the heavily infested territory, the direction of which was governed in part by the cropping of the adjacent territory but in great measure also by the direction of the prevailing winds at times when the insects were on the wing, especially in spring when emerging from hibernation and in fall when in search of winter quarters. These flights commonly occurring on warm sunny days when the winds are from southerly and westerly directions, the chinch-bugs were carried mainly to the north and east with a resulting extension of the area of infestation, year after year, in those directions. The outbreak was brought to a conclusion in the spring and early summer of 1915 by heavy beating and flooding rains coming at times when the young bugs were hatching rapidly from the egg.

The principal measures for the control of a chinch-bug outbreak are the burning out of the insects in their winter quarters and their

destruction at harvest time by means of impassable barriers and lines of post-hole traps placed beside infested fields of wheat. Altho winter burning on a large scale proved impracticable in Illinois owing to wet and snowy winters, small-scale field experiments with this operation, under conditions locally and temporarily favorable, destroyed from 50 to 75 percent of the chinch-bugs under the harborage burned over.

With a view to finding a better material than coal-tar for making the barriers against the escape of chinch-bugs at wheat harvest, many experiments were made in Illinois, in Texas, and in Arizona, with various more or less similar substances, resulting in the selection of a petroleum product, a residue of distillation, containing 70 percent of asphaltic materials and known as road oil No. 7. This was virtually a perfect substance for its purpose, lasting from five to ten or more times as long as coal-tar, without renewal. It had the disadvantage, however, that it was not on the market, and must be made at Whiting, Ind., solely for this special use; must consequently be ordered some time in advance; and because of the delays in transportation, was frequently received after the emergency for which it was needed had passed. An attempt to secure the same results with a road oil of the same composition made at a refinery within the infested district resulted disastrously because of the different physical qualities of this road oil, due to the different character of the crude oil supplied to this refinery.

A farmer's chance experiment made in 1912 showed that crude creosote was almost as effective as coal-tar or the road oils. It had the advantage that it could always be obtained without delay in any desired quantity and from near-by sources of supply; and this was the substance principally used during the last year or two of the outbreak. Experiments showed that creosote differed from coal-tar and the road oils in the cause of its effectiveness, the latter being impassable because they were thick and sticky, and the creosote repelling the insects by the odorous vapors given off.

Field experiments with practical operations, especially in 1910, 1911, and 1912, showed that an effective barrier could be made and maintained at an expense for labor and materials varying from $1.50 to $2 per day per mile, the difference depending mainly upon the character of the season.

Under certain conditions it is desirable to kill chinch-bugs by means of an insecticide spray. Kerosene emulsion, in use for this purpose since 1882, being difficult to prepare and dangerous to the plants unless very carefully used, experiments were made to find other more satisfactory substances, with the result that a tobacco extract known as Black Leaf 40 was found highly effective in ratios of half an ounce to a gallon of water in which half an ounce of soap had been dissolved. Further experiments showed that soap solutions alone, three ounces to the gallon of water, were almost equally useful.

Data obtained concerning the results of the final campaign of 1914 showed that in thirteen counties of west-central Illinois two thousand barrels of creosote and a thousand barrels of coal-tar were used, together with considerable quantities of other materials, and that at least fifteen hundred miles of barrier were maintained in these counties at a total cost of $40,500 for materials and labor, with the result to protect against injury by chinch-bug corn fields aggregating 190,590 acres and yielding 4,764,750 bushels of corn, a fourth of which yield, worth $715,000, was due to the protective measures. This was a net profit of $674,212 on an investment of $40,500, a ratio of 1665 per-cent. If each infested wheat field had been wholly surrounded, the profit would still have been 342 percent on the cost of labor and materials.

Since it has proven impossible to induce farmers to *surround* infested fields at harvest time with impassable barriers and lines of traps, owing to the fact that the benefit of this complete operation depends upon its performance by all owners of infested fields, legislation is proposed similar to that in force for the control of the San Jose scale and other pests of horticulture, but applying to chinch-bugs, army-worms, Hessian flies, and a considerable series of insect pests of agriculture, the effective control of which requires community action. It is advised that any law of this character should be given effect only by a proclamation of the Governor, based upon information given him by the State Entomologist, and specifying the territory, time, and extent to which the law shall apply.

FIG. 1. Field with growth of bunch-grass (*Andropogon*).

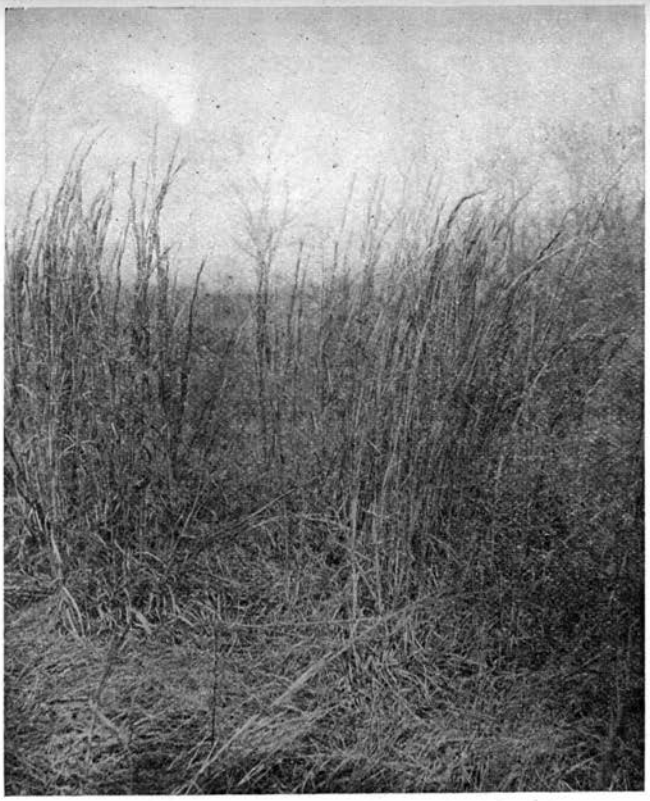

FIG. 2. Growth of bunch-grass (*Andropogon virginicum*).

FIG. 3. Incompletely burned crowns of bunch-grass (*Andropogon*).

FIG. 4. Sumacs along fence, providing winter quarters for chinch-bugs.

FIG. 5. Road-oil line around a field of wheat nearly destroyed by chinch-bugs. Note the perfect condition of the corn field beside the wheat.

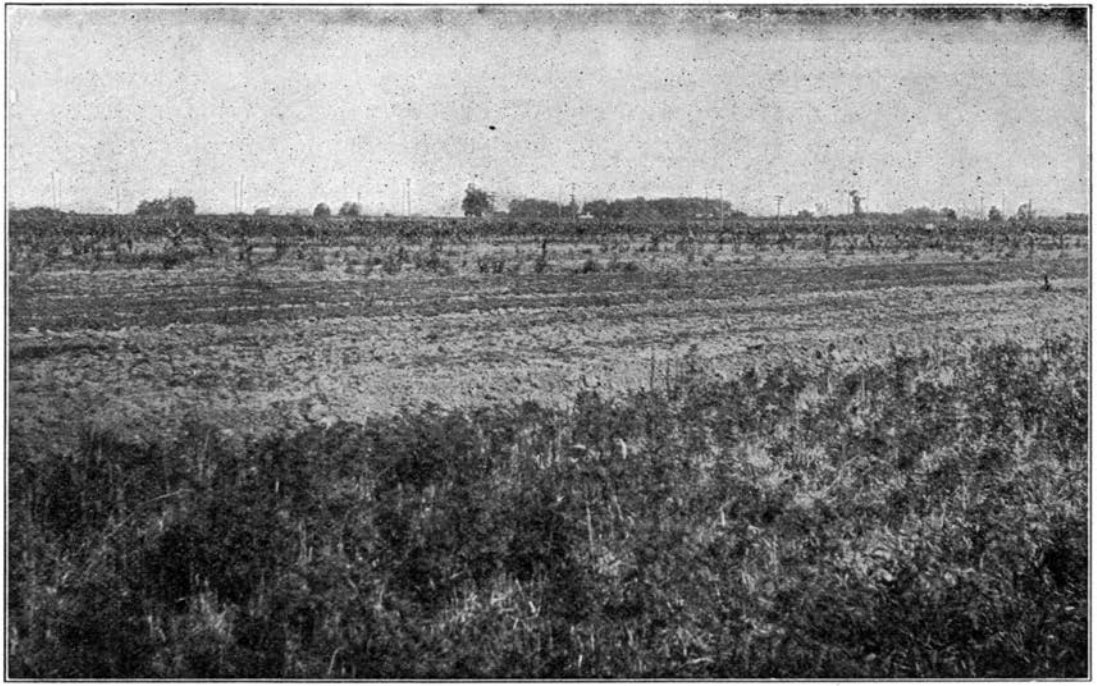

FIG. 6. An unprotected corn field, 1912. The chinch-bugs entered it from the field of wheat, a little of which is shown in the foreground.

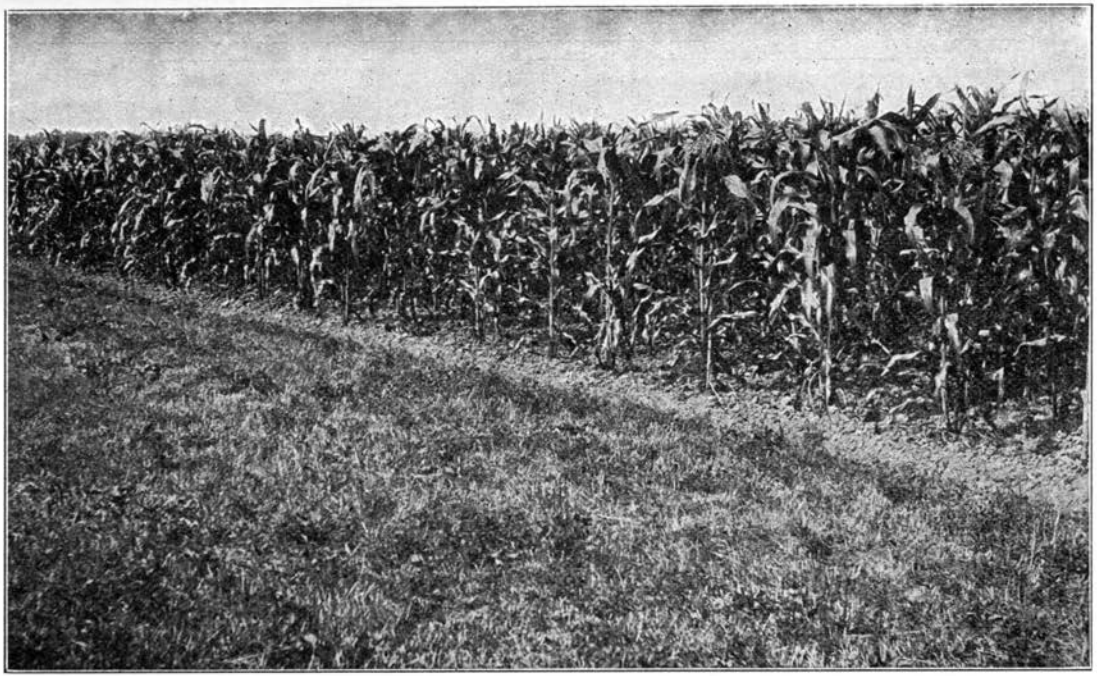

FIG. 7. A protected corn field, 1912. Road-oil and post-hole traps between the corn and the wheat, by which millions of the bugs were caught.